NOTICE OF APPEAL

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES

WATER COUNCIL

06-04 WC

RECEIVED

APR 0 5 2006

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NOTICE OF APPEAL

NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
WATER COUNCIL

REGARDING: New Hampshire Department of Environmental Services Denial of Waiver Request from Env-Ws 386.61(h)(4) "Canobie Lake No-Swim Rule".

APPELLANTS:

Stephen M. Andrews
48 Woodvue Rd.
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44 Woodvue Rd.
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RELIEF SOUGHT: In accordance Env-WC 203, the Appellants seek relief from Env-Ws 386.61(h)(4) as provided for by Env-Ws 386.04. The Appellants reside on Lakefront, Residentially-Zoned Property. Relief is sought only for the Appellants' Properties and the like.

The NHDES is required to grant the relief upon finding that the waiver proposal "...shall be adequate to ensure that the intent of RSA 485.24 and RSA 485.25 is met." The NHDES denied the request, arguing that the waiver application failed to meet this requirement.

The Appellants maintain that the NHDES was arbitrary and capricious in this denial and that the waiver proposal is adequate to ensure that the intent of RSA 485.24 and RSA 485.25 is met.

SATEMENT OF FACTS: The facts upon which the Council is expected to rely in granting relief are those underlying the original Waiver Application attached hereto (*Exhibit* 2).

The Department's decision was arbitrary and capricious as evidenced by the following:

1) The Department ignored its own action of consenting to a direct water transfer from Arlington Pond [swimming permitted] into Canobie Lake in April of 2002 -- this clearly voids the Department's pretense of a 'multi-barrier approach to protect the purity of Canobie Lake' as it relates to swimming. *(Exhibit 5).*

2) The Department ignored its own analysis of the effects of a direct water transfer from Arlington Pond [swimming permitted] into Canobie Lake which states that "*...the source water meets applicable water quality standards, and the receiving water will continue to meet applicable water quality standards....*" (*Exhibit 5).*

3) The Department ignored the 2002 ruling by the Water Council in the Appeal of John Dixon *et al* regarding the Lake Sunapee No-Swim Rule which found that the presence of a sand filtration was enough to ensure the intent of RSA 485.24 and RSA 485.25 was met (*Exhibit 6, page 2*).

The Water Council's ruling was subsequently upheld by the New Hampshire Supreme Court in 2004 following a challenge by the NHDES. (*Exhibit 7).*

The Canobie Lake No-Swim Rule is:

1) ARBITRARILY APPLIED: only 53% of surface water sources in the state suffer total bans on swimming –those that do suffer bans, suffer primarily as a result of turn-of-the-century legislation enacted prior to modern sanitation and water treatment, not as the result of unique watershed, biological or community conditions. (*Exhibit 3*).
2) ARBITRARILY ENFORCED: see emails from Canobie Lake Protective Association Officers encouraging quiet swimming, acknowledging personal swimming and acknowledging 'resident dockside swimming'. (*Exhibits 8 & 9*).
3) ARBITRARILY IGNORED: see NHDES approval of direct water transfer from Arlington Pond [swimming permitted] into Canobie Lake. Of note is the fact that alleged swimming contamination does not even rise to the level of an aesthetic concern in the department's own report. (*Exhibit 5*).

The Appellants intend to submit additional information and evidence at a later date under Env-WC 203.03(c) and may include testimony, photographs, plans and other material.

Lastly, so as preserve the Appellants' right to argue the merits of the NHDES' *seventeen* discussion points listed in the Denial Letter should it be necessary, the Appellants have included comments to the discussion (*Exhibit 10*).

Dated this 3rd day of April, 2006.

Respectfully Submitted,

Stephen M. Andrews

John Carpenter

LIST OF EXHIBITS

Exhibit 1

The State of New Hampshire

Department of Environmental Services

Michael P. Nolin
Commissioner

March 9, 2006

Stephen M. Andrews
48 Woodvue Rd.
Windham NH 03087

John Carpenter
44 Woodvue Rd.
Windham NH 03087

Re: "Waiver Request Env-Ws 386.61(h)(4) (Canobie Lake No-Swim Rule)"

Dear Messrs. Andrews and Carpenter:

By letter dated November 14, 2005, you ("the Petitioners") requested a waiver pursuant to Env-Ws 386.04 to allow swimming in Canobie Lake in Windham, New Hampshire. Canobie Lake is a surface water supply reservoir used as a drinking water supply by the Town of Salem. You requested the waiver as owners of two properties with waterfront on Canobie Lake, 44 Woodvue Road and 48 Woodvue Road, both located in the Town of Windham.

The Water Division of the Department of Environmental Services (the "Division") received the Petition on November 15, 2005. Coincidentally, on November 23, 2005, minor amendments to Env-Ws 386.04 became effective. The new rules provide clarification of the waiver request and decision procedures and generally lay out the process and decision criteria more clearly. The Division decision considers both rules, which are not different in substance, for purposes of evaluation of this waiver request. For simplicity, except if noted, the rule citations below are from the rules in effect after November 23, 2005.

In addition to the waiver request letter, four letters were received concerning this request:

- Letter dated December 15, 2005 from the Salem Town Manager, Dr. Henry E. LaBranche, on behalf of the Board of Selectmen;
- Letter dated December 19, 2005 from Mr. Richard H. Hannon, President of the Canobie Lake Protective Association ("Lake Association"), on behalf of the Lake Association Board of Directors. Mr. Hannon described the Lake Association as a 25-year old voluntary membership association of approximately 80 lakefront property owners in both Salem and Windham;
- Letter dated December 20, 2005 from Windham Town Administrator, David Sullivan, on behalf of the Board of Selectmen; and
- Letter dated January 4, 2006 from Mr. Stephen M. Andrews, one of the petitioners.

WAIVER REQUEST CRITERIA

Under Env-Ws 386.04(b)(2) in effect on November 15, 2005, each request for a waiver shall include the following information:

1. A description of the affected property, including town, street address, and tax map and lot number (this requirement was added in the November 23 rule version);
2. A specific reference to the section and paragraph for which a waiver is sought;
3. A full explanation as to why the waiver is necessary and demonstration of hardship caused if the rule is adhered to;
4. A full explanation of the alternatives that will be implemented if the waiver is granted, with backup supporting data; and
5. A full explanation of how the granting of the waiver is consistent with the intent of RSA 485:24 and RSA 485:25 and would have a just result.

The Division finds that the information provided in the Petitioners' letter dated November 14, 2005 sufficiently addresses the information requirements to enable the Division to render a decision on the waiver request, but does not demonstrate that Petitioners are entitled to a waiver.

DECISION CRITERIA

Under Env-Ws 386.04(f) in the November 23, 2005 rules, "The department shall grant a request for waiver upon finding that:

1. The proposal shall be at least equivalent to the specific requirement contained in the rule;
2. If the proposal was not equivalent to the requirement contained in the rule, it shall be adequate to ensure that the intent of RSA 485:24 and RSA 485:25 is met; or
3. Denial of the waiver request would result in loss of all economically beneficial or productive use of an existing property."

If the request is denied, the Division must state the reason(s) for the denial.

DECISION AND FINDINGS

The waiver request is **DENIED** based on the following findings:

1. The Division finds that the proposal is not equivalent to the specific requirements in Env-Ws 386.61(h)(4), Protection of the Purity of The Water of Canobie Lake and Its Watershed, as adopted under the authority of RSA 485:24, I. The rule provides that "A person shall not bathe or swim or engage in other body-contact activities in [Canobie Lake]." Allowing swimming in Canobie Lake, a primary, terminal water supply reservoir, would not afford protection equivalent to the existing requirements. Furthermore, this would be inconsistent with the letter and spirit of RSA chapter 485, as well as with well-recognized best management practices and standards in the water works industry for drinking water quality protection.

2. The Division finds that granting the waiver would contravene the intent of RSA 485:24. The overall purpose of Chapter 485 is "to provide a comprehensive drinking water protection program for the citizens of New Hampshire." (RSA 485:1, I.) Part of this comprehensive program is to encourage and assist water suppliers in implementing a multiple-barrier approach (see Discussion point 5). The subdivision in which RSA 485:24 appears, entitled "Water Pollution Control," specifically references "bathing" as one of the activities which DES may prohibit by rule in a water supply protection area, and makes it a misdemeanor to violate such a rule. (See RSA 485:22 and 23). Specifically, the purpose of RSA 485:24 is to enable the Department to exercise its judgment in helping to provide appropriate protection for water supply sources by adopting "such rules under RSA 541-A as it may deem best to protect the water or ice supply against dangerous contamination." The Department is guided in its exercise of discretion by the entire subdivision, which specifies the types of actions that may contaminate the water supply. (see, e.g. RSA 485:17 (leaving substances in or near water supply); RSA 485:19 (dead animal or other offensive material); RSA 485:21 (fishing, boating, horse racing on ice); RSA 485:22 (bathing); RSA 485:30 (sewage).) The Division finds that the existing rule is an appropriate means to protect the water supply because the rule ensures the presence of multiple-barrier protections advocated by the United States Environmental Protection Agency (USEPA) to ensure compliance with the Safe Drinking Water Act and the best management practices of the waterworks industry.

3. The Division finds that RSA 485:25 is not directly relevant, as it pertains only to interstate waters used by adjoining states as drinking water supplies. Canobie Lake is wholly within New Hampshire and is not used by water suppliers from adjoining states.

4. The Division finds that denial of the waiver request will not result in loss of all economically beneficial or productive use of an existing property, as required in Env-Ws 386.04(f)(3). The

Petitioners' lots are now active residential properties which clearly have substantial economic value.

Discussion of this decision, including further explanation of the reasons for denial consistent with the requirements of Env-Ws 386.04(i) is presented below.

DISCUSSION

1. Env-Ws 386.61, Protection of the Purity of the Water of Canobie Lake and Its Watershed, which the Petitioners seek to partially waive, is a part of DES rules Env-Ws 386, Protecting the Purity of Regulated Watersheds. In the purpose statement to Env-Ws 386, Env-Ws 386.01 states that "the purpose of these rules is to recognize the importance of those surface water supplies that are used as sources of public water supply and to provide methods for reasonable watershed management so as to maintain high levels of water quality."

2. Canobie Lake, located in Salem and Windham, New Hampshire, is the primary water supply reservoir for the Town of Salem. DES rule Env-Ws 386.61, Protection of the Purity of the Water of Canobie Lake and Its Watershed (Canobie Lake Watershed Rule), is applicable to Canobie Lake. Env-Ws 386.61 in its current form has been in effect since June 4, 1997. Predecessor agencies, including the Water Supply and Pollution Control Commission and the State Board of Health, have had similar restrictions including swimming prohibitions for Canobie Lake in place as early as 1903.

3. The New England Water Works Association (NEWWA) includes waterworks professionals from across New England that establish best management practices for the New England waterworks industry. In its December 1995 Final Revised Policy of the New England Water Works Association entitled "Resolution & Policy Concerning Recreational Use of Public Water Supplies,"NEWWA states in part that "*public water suppliers support the concept of multiple barrier protection of drinking water supplies to maximize public health by: 1. Source water protection, 2. Treatment, which may include filtration, 3. Preservation of finished water, 4. Monitoring, 5. Training and certification.*" In the NEWWA policy, terminal and primary storage reservoirs are "*reservoirs and reservoir system components providing principal and/or end storage of water prior to treatment and delivery of finished water to the distribution system.*" The NEWWA policy further states that "*recreational use of terminal reservoirs and adjacent land is contrary to the basic function of furnishing safe, palatable water supply to customers and should be prohibited to the greatest extent possible, but, **in no event should direct contact with the reservoir be allowed** (emphasis added). In addition, activities allowed to occur on adjacent lands should prohibit contact with water in the reservoir.*" This policy summarizes standard industry practice (best management practices) for New England water suppliers.

4. The American Water Works Association (AWWA) policy on "Recreational Use of Domestic Water Supply Reservoirs," revised June 23, 1996, states in part that "*It should be recognized that uncontrolled recreational use of domestic water supply can result in deteriorated water quality which increases the potential for a waterborne disease to occur... The decision concerning recreation and the associated treatment should be made by utilities based on water quality concerns, on applicable laws and regulations, and on information provided by AWWA, the US Environmental Protection Agency and other organizations that conduct research and present technical reports. This information should be used to balance and assess public demand for greater utilization of water resources.*"

5. The U.S. Environmental Protection Agency (USEPA) further supports a multiple barrier approach for water supply protection. "*The Safe Drinking Water Act (SDWA), amended in 1996, promotes a multiple-barrier approach to safeguarding the nation's water supply. This multiple-barrier approach goes beyond the traditional emphasis on treatment to address new challenges and reflects a better understanding of the need for a coordinated source water protection effort. The multiple-barrier approach encompasses delineation and prevention of contamination of drinking water sources, treatment appropriate to the quality of the source water, well-engineered*

distribution and storage systems, operator training and certification and an informed and involved public. Preventing contamination, therefore, is one of the key elements of the multiple-barrier approach." (U.S. EPA, *State and Federal Source Water Assessment and Protection, Program Measures – Final Reporting Guidance*, March 2005, p 1)

6. Body-contact recreation is an established source of fecal contamination in lakes and reservoirs where this activity is permitted. A study on the impacts of direct body contact recreational activities, including swimming and other on-water sports, on water quality, concluded "*a modeling-based risk assessment was conducted to assess the potential public health consequences to downstream potable water users consuming water from this reservoir if BC ("direct body contact") recreation was permitted. Results of the study indicated that the annual risk of waterborne illness would increase three times above background, despite conventional treatment. Moreover, the occurrence of high-loading pathogen events associated with BC recreation was observed to significantly increase the daily risk of waterborne illness to downstream consumers.* (Mic H. Stewart *et al.*, "Predicted Public Health Consequences of Body-contact Recreation on a Potable Water Supply Reservoir," *Journal of the American Water Works Association,* May 2002.) A related study found that all reservoirs studied would exceed US EPA's target of 1/10,000 annual risk of infection for treated surface water if swimming were allowed (Michael A. Anderson, *et. al.*, "Modeling the Impact of Body-Contact Recreation on Pathogen Concentrations in a Source Drinking Water Reservoir", *Water Research,* November 1998).

7. Both the Stewart and Anderson studies conclude that allowing swimming in a terminal water supply reservoir does not provide the same level of protection as with the no-swim rule. On this basis alone, the petition fails the test of "at least equivalent" or "if not equivalent, adequate to ensure the intent of RSA 485:24 and RSA 485:25" (see Env-Ws 386.04(f))

8. The swimming prohibition contained in the Canobie Lake Watershed Rules, Env-Ws 386.61(g), is consistent with the conclusions of the available research, best management practices and policies of the water works industry for protection of public water supplies, including those of NEWWA, AWWA and the USEPA.

9. The "no swim" restrictions for Canobie Lake are not unique as protection measures. Numerous other water suppliers in New Hampshire, through DES regulation, as well as in other New England states have restrictions at least as stringent on water supply reservoirs to protect and preserve drinking water quality. In New Hampshire, these include those for major water supplies such as Lake Massabesic, which serves Manchester, the Pennichuck Brook system ponds which serve Nashua, Penacook Lake which serves Concord and many others.

10. The Petitioners argue that because the Salem water treatment plant also receives water from Arlington Pond (where swimming is permitted) from, at the most, October to April that the "no swim" rule should be removed from the Canobie Lake Watershed Rules. Arlington Pond provides Salem with additional water supply capacity that enables Canobie Lake to be filled up to capacity over the winter, peaking in May just prior to the peak summer water use demand months, thus increasing overall water supply capacity. Under local agreement, restrictions exist on the use of Arlington Pond by Salem that include no use from May through September and other conditions such as maintenance of certain water levels in the pond. These local conditions were agreed to by Salem to ensure support for funding for the Arlington Pond intake and supply line and enable Salem to partially address critical water quantity needs. The use of Arlington Pond in this way perhaps results in a marginally higher risk of contamination from water contact recreation due to late season swimming or slow die off of contamination by viruses or cysts. However, this does not form a reasonable basis to lower the existing source water protection measures in Canobie Lake by elimination of the "no swim" rule. Furthermore, the peak swimming season would coincide with the peak use period for Canobie Lake further increasing the potential for contamination relative to Arlington Pond.

11. The Petitioners also argue that since other water supply water bodies for other communities in New Hampshire do not have swimming restrictions, neither should Canobie Lake. This suggests that the allowance of less-than-ideal "grandfathered" activities in some water supply reservoirs should be considered the "default" for all terminal reservoirs. DES disagrees that the least protective "lowest common denominator" should be pursued for protection of New Hampshire's surface water supplies based on compromises made long ago on some other reservoirs to enable less protection.

12. The Petitioners compare Canobie Lake to Lake Sunapee, where the Water Council concluded that swimming restrictions should be relieved. We believe that this is an "apples to oranges" comparison because the local conditions are substantially different. The Canobie Lake water supply is much more vulnerable to potential impacts from swimmers than that of Lake Sunapee. First, the Town of Sunapee's intake in Lake Sunapee is nearly twice as deep as Salem's Canobie Lake intake (38 vs. 20 feet). Second, Lake Sunapee is more than 20 times larger than Canobie (6,600 vs. 300 million cubic meters) with 5.7 times more shoreline (30 vs. 5.2 miles). As a result, the density of swimmers on Canobie could potentially be much higher than those on Sunapee.

13. The Petitioners mention that Canobie Lake residents have been swimming in the lake without health incident, and that the no-swim rule has not been enforced. This claim has been refuted by the Town of Salem, the Town of Windham and the Lake Association. According to the Town of Salem, public access areas to Canobie Lake have long been posted against swimming. Over the past six years, the Salem Police Department have logged and responded to eight calls reporting swimmers in the Lake; in each case when the swimmers were found, the police ejected them from the Lake. According to David Sullivan, Windham Town Administrator, when the Windham Police Department receives complaints regarding swimming in Canobie Lake, the response is typically to phone or visit the home where the swimming is alleged to be taking place and remind residents that they need to comply with DES's swimming prohibition. This response has been effective at controlling swimming on the Town of Windham side of the lake. In its December 19, 2005 letter to the Division, the Lake Association states, "The no-swim rule has been enforced by the lake residents, sometimes with kind warnings that swimming is illegal, and sometimes with calls to law enforcement. There has been no widespread flagrant violation of the no-swim rule. Residents who have lived on the lake for many years and many generations would certainly attest to consistent and general conformance with the no-swim rule."

14. Granting the requested waiver has the potential to set a precedent that would eventually enable use by a tremendous number of swimmers in the lake, for example, due to the presence of Canobie Lake Park on its shores. This park has thousands of customers every day over the course of the summer. The presence of an amusement park on Canobie Lake's shores creates a substantially higher potential for contamination by swimmers as compared to any other public water supply reservoir in New Hampshire.

15. Water from Canobie Lake is treated by conventional filtration and chlorination prior to delivery to the Town of Salem water system. The presence of treatment does not eliminate the need for other protective measures, because some pathogenic organisms are more resistant to such treatment than others, and because treatment processes have been known to fail on occasion. Conventional treatment represents one component of multiple-barrier protection consistent with water works industry best management practices and as advocated by USEPA for protection of the public health. Consequently, the presence of water treatment, while improving the level of public health protection, does not in itself justify removal of the "no swim" rule.

16. The Salem Board of Selectmen, the Windham Board of Selectmen, and the Canobie Lake Association have all submitted letters opposing the proposed change to allow swimming in Canobie Lake. The Town of Salem cited increased monitoring requirements, increased treatment costs, and possible contamination if swimming were to be allowed. The Town of Windham also expressed concerns over water quality, particularly the introduction of pathogenic

organisms into the water supply. The Lake Association expressed concerns over water quality, the overall nature of the use of the lake, and lake ecology.

17. Finally, the Petitioners suggest that a three-part test established in a court case concerning a local zoning and land use question in Simplex Technologies, Inc., v. Town of Newington, 145 N.H. 727 (2001) is applicable to this waiver request. The Petitioners further suggest that this test effectively supercedes or "trumps" the waiver criteria and procedures contained in Env-Ws 386. The Department disagrees that the Simplex case is directly applicable to this waiver request. The New Hampshire Supreme Court in Simplex was interpreting a specific statute, RSA 674:33, I, which applies to variances from local zoning ordinances. Neither that statute, nor the Simplex standard, applies directly to a DES decision whether to grant a waiver under Env Ws 386.04. Instead, the Division has weighed the merits of the appeal based on the criteria set forth in Env-Ws 386 as required by statute. The Division has denied the waiver request in part considering that this denial will not result in loss of all economically beneficial or productive use of an existing property, as required in Env-Ws 386.04(f)(3), since the Petitioners' lots are now active residential properties which have substantial economic value, and from which swimming has been prohibited for many years. Furthermore, as described above, swimming in a primary, terminal water supply reservoir carries risk of negative impacts on drinking water quality. Therefore, the "no swim" rule is reasonable for Canobie Lake as part of the multiple-barrier approach for protection of Salem's primary drinking water supply.

Under Env-WC 203, any aggrieved party may appeal this decision to the Water Council. Any appeal must be filed with the Water Council within 30 days.

Sincerely,

COPY

Harry T. Stewart, P.E.
Director, Water Division

cc: Henry E. LaBranche, Town Manager, Town of Salem
David Sullivan, Town Administrator, Town of Windham
Richard H. Hannon, President, Canobie Lake Protective Association
Michael P. Nolin, DES Commissioner
Michael J. Walls, DES Assistant Commissioner
Rene Pelletier, DES, LRMP
Sarah Pillsbury, WSEB Administrator, DES
Paul Susca, Source Water Protection Coordinator, DES

Exhibit 2

November 14, 2005

48 Woodvue Rd.
Windham, NH 03087

Harry T. Stewart, P.E.
Director, Water Division
NHDES
PO Box 95
Concord NH 03303-0095

RE: Waiver Request Env-Ws 386.61(h)(4) (Canobie Lake No-Swim Rule)

Dear Mr. Stewart,

Please accept the following Waiver Request as outlined in Env-Ws 386.04.

I. AFFECTED PROPERTIES:

This request is filed on behalf of two residential properties, improved by single family homes in the town of Windham, NH identified by the following:
Property 1: 48 Woodvue Rd., Windham, NH; Map 18, Block L, Lot 502
Property 2: 44 Woodvue Rd., Windham, NH; Map 18, Block L, Lot 500

II. WAIVER REQUEST FOR:

This waiver is sought for relief in its entirety from Env-Ws 386.61(h)(4), 'Prohibition against swimming in Canobie Lake' hereafter "NO-SWIM RULE"

BACKGROUND INFORMATION:

The town of Salem owns and operates a single water treatment plant that draws water from two sources, Arlington Pond and Canobie Lake. Arlington Pond Water is drawn from October through April; Canobie Lake from May through September.

Arlington Pond is a fully recreational lake – swimming and body contact is permitted. Canobie Lake activities are restricted by Env-Ws 386.61(h)(4) and swimming is prohibited.

Water from the Salem Treatment Facility meets or exceeds all State and Federal regulations whether drawn from Arlington Pond or Canobie Lake.[1]

Salem's water treatment plant was constructed in 1995 and employs modern filtration and treatment practices, including chlorination and dual-media filtering to ensure the safety of the water supply.

Canobie Lake residents have been swimming in the waters for generations without health incident. The NO-SWIM RULE has not been enforced.

III. NECESSITY OF WAIVER AND HARDSHIP:

This waiver is necessary as the NO-SWIM RULE unnecessarily interferes with the reasonable use and enjoyment of waterfront properties along Canobie Lake.

In considering this application which requires a demonstration of hardship, it is necessary to look to recent zoning and land use case law to adequately assess the hardship claim. Env-Ws 386 and this waiver request are the practical and legal equivalents to zoning bylaws and variance applications.

For matters involving governmental regulation of Land Use, the New Hampshire Supreme Court has outlined clear standards for meeting hardship requirements in Simplex Technologies, Inc., v. Town of Newington & a. 2001. The court established that applicants may establish unnecessary hardship by proof that:

(1) A zoning restriction as applied to their property interferes with their reasonable use of the property, considering the unique setting of the property in its environment;
(2) No fair and substantial relationship exists between the general purposes of the zoning ordinance and the restriction on the property; and
(3) The variance would not injure the public or private rights of others.

This hardship test is a noted departure from the strict, pre-2001 standard as the Supreme Court has sought to "...adopt an approach more considerate of the constitutional right to enjoy property."[2]

[1] 2004 Salem Water Quality Report, Salem Department of Public Works
[2] Simplex Technologies, Inc., v. Town of Newington & a. 2001

ESTABLISHING THE HARDSHIP

FIRST CRITERION-- INTERFERENCE WITH REASONABLE USE:

Under the first test for establishing hardship, it is obvious that swimming is, without question, a reasonable use of Lakefront Property and that the NO-SWIM RULE interferes with this reasonable use.

SECOND CRITERION -- FAIR AND SUBSTANTIAL RELATIONSHIP TO THE RESTRICTION:

The second criterion requires careful consideration. It is important to understand that the NO-SWIM RULE is a carryover from turn-of-the-century legislation designed to protect against outbreaks of typhoid.[3] In that sense, it was, perhaps, prudent to adopt such a restriction -- typhoid was a very real threat. Since then, however, typhoid has been effectively eliminated from the United States; only 400 cases of domestic typhoid occur annually, 70% of which are acquired during international travel.[4]

Further, technology and modern sanitation have eliminated the need for the NO-SWIM RULE as demonstrated not only by the successful treatment of Canobie Water exposed to casual swimming, but more dramatically by the successful treatment of Arlington Pond water in which swimming is ubiquitous.

Therefore, in the modern context, the NO-SWIM RULE fails to bear a "fair and substantial relationship" to the general purpose of the restriction.

THIRD CRITERION – NO INJURY TO OTHERS RIGHTS:

Clearly, lakefront residents will not be injured by a suspension of the NO-SWIM RULE. To the contrary, abutters will benefit from the restoration of littoral rights. Nor will Salem water customers be injured, as the treatment plant has a well-established record of success in treating Canobie Lake and Arlington Pond, both of which host swimmers to varying degrees.

IV. EXPLANATION OF ALTERNATIVES:

No alternatives will be implemented in the granting of this waiver for the affected properties. It is a binary consideration -- either the NO-SWIM RULE *is* a necessary restriction of individual's rights to enjoy their property, or it is not and should be suspended.

[3] 1899 Regulation, Secretary's Report, Protection of Water Supplies
[4] Bulletin, Typhoid Fever, Center for Disease Control, January 10, 2005

Perhaps a case can be made that this waiver should apply only to residential abutters of the lake and guests thereof and not to the public at large -- it is unclear whether a hardship claim by the general public could be substantiated. That, however, is beyond the scope of this petition.

V. CONSISTENCY WITH RSA 485:23 and 485:24

A suspension of the NO-SWIM RULE is consistent with the protection of water supplies. It is clear that the rule is out-dated and unnecessary. Consider that:

1) Swimming has been an integral activity in Canobie Lake for generations without incident.
2) Many surface water bodies in New Hampshire successfully function as recreational water supplies in which swimming is permitted (Lake Sunapee and Arlington Pond to name two). In fact, only 30 of 57 surface water supplies are subject to Env-Ws 386.
3) The Salem Treatment plant employs modern chlorination and filtration techniques that were not available at the time the NO-SWIM RULE was originally adopted.
4) The Salem Treatment plant successfully treats Arlington Pond water which is fully recreational. This same plant treats Canobie Lake water, but swimming is prohibited. No justification exists for the lack of parity between the two water sources.
5) In a written brief, the DES demonstrated that the department, itself, does not truly consider alleged swimming-related contaminants to be a practical threat to Canobie Lake. Witness:

    On April 3, 2002, the Department of Environmental Services approved an application by the Town of Salem to transfer up to 100,000,000 gallons of water from Arlington Pond [swimmable] directly into Canobie Lake [swimming prohibited]. The DES concluded that "*...the source water meets applicable water quality standards, and the receiving water will continue to meet applicable water quality standards....*"[5]

    Further, the DES cited only 3 concerns for the transfer – phosphorous levels, exotic plant contamination, and aesthetics of water color. Conspicuously absent from the report was any concern or mention of the potential transfer of swimming-related contaminants.

    A limited transfer was subsequently made. Water quality from the treatment plant was unaffected.

6) In an October, 2001 denial of a similar waiver application by John Dixon of Sunapee, the DES presented an expanded role of the Lake Sunapee NO-SWIM

[5] Letter, Department of Environmental Services to Mr. Jeffrey Towne, April 3,2002

RULE as a necessary element of a "multi-barrier approach" to water protection as the basis for denying the application.

Upon appeal, the Water Council found that no such multi-barrier approach existed as evidenced by the lack of enforcement of the Lake Sunapee NO-SWIM RULE. Further, the Water Council found that the single barrier sand filtration system "would be adequate to ensure the intent of RSA 485:24 and RSA 485:25 is met."[6]

The Water Council's position overturning the DES waiver denial was subsequently upheld by the New Hampshire Supreme Court.[7]

It is clear from the evidence presented here, that the DES is obligated to grant the requested waiver as the New Hampshire Supreme Court has ruled that ordinances "must be reasonable, not arbitrary…."[8] In the modern context, the NO-SWIM RULE is completely arbitrary.

Please advise at your earliest convenience.

Sincerely,

For 48 Woodvue Rd.

COPY

Stephen M. Andrews

For 44 Woodvue Rd.

COPY

John Carpenter

[6] Decision and Order, State of New Hampshire Water Council, Docket No. 01-20 WC, Appeal of John Dixon et al., January 23, 2003
[7] Appeal of New Hampshire Department of Environmental Services, Case No. 2003-0382 (2004)
[8] Town of Chesterfield v. Brooks, 126 N.H. 64,69, 489 A.2d 600, 604 (1985)

Exhibit 3

EPAID	Source ID	Source Name	Intake Location (Town)	System Name	Watershed Acreage	Rules	Sq.Mi.	Water body acres	Water body	No swim	No boat	No nothing	
2271010	001	LAKE SUNAPEE	Sunapee	SUNAPEE WATER WORKS	33,245	386.64	51.9	4066.0	Lake Sunapee	~~partial~~			
1471010	001	LAKE MASSABESIC	Manchester	MANCHESTER WATER WORKS	30,073	386.47	47.0	2569.0	Massabesic	all	partial	partial	
1281010	001	PAUGUS BAY	Laconia	LACONIA WATER WORKS	231,440	386.37	361.6	1228.0	Paugus Bay	partial			
1521010	001	LAKE WAUKEWAN	Meredith	MEREDITH WATER DEPARTMENT	9,504	386.49	14.9	927.0	Lake Waukewan	partial			
2051010	001	CANOBIE LAKE SURF	Salem	SALEM WATER DEPARTMENT	1,860	386.61	2.9	375.0	Canobie Lake	all			
0501010	002	PENACOOK LAKE	Concord	CITY OF CONCORD	2,812	386.21	4.4	362.0	Penacook L.	all			
1951010	009	BELLAMY RESERVOIR	Madbury	PORTSMOUTH WATER WORKS	15,392	386.58	24.1	362.0	Bellamy Res	all	partial	partial	
0351010	001	CANAAN STREET LAKE	Canaan	CANAAN WATER DEPARTMENT	1,656	386.18	2.6	290.0	Canaan St. L.	partial	partial	partial	
0081010	001	BRADLEY LAKE	Andover	ANDOVER VILLAGE DISTRICT	2,419	386.10	3.8	165.0	Bradley L	partial			
1141010	001	LOON POND	Hillsborough	HILLSBOROUGH WATER WORKS	1,266	386.34	2.0	154.0	Loon Lake	all			no r
1241010	005	BABBIDGE POND RESERVOIR	Roxbury	KEENE WATER DEPARTMENT	3,594	386.36	5.6	148.0	Woodard Pond	all	all	all	
2561010	001	UPPER BEACH POND	Wolfeboro	WOLFEBORO WATER & SEWER DEPT	853	386.69	1.3	144.0	Upper Beech Pd.	all	all	all	
0991010	002	TOBY RESERVOIR	Temple	GREENVILLE WATER DEPARTMENT	5,983	386.30	9.3	123.0	Tobey Res.	all	all	all	
2001010	001	ROUND POND AND ROCHESTER RESERVOIR	Rochester	ROCHESTER WATER DEPARTMENT	7,196	386.59	11.2	109.0	Round Pond	all	all	all	
1621010	002	HARRIS POND	Nashua	PENNICHUCK WATER WORKS	16,247	386.50	25.4	92.0	Bowers Pond	all			
1621010	002	HARRIS POND	Nashua	PENNICHUCK WATER WORKS	16,247	386.50	25.4	78.0	Harris Pond	all			
1741010	001	GILMAN POND	Unity	NEWPORT WATER WORKS	919	386.56	1.4	68.0	Gilman Pond	all	all	all	
1621010	002	HARRIS POND	Nashua	PENNICHUCK WATER WORKS	16,247	386.50	25.4	57.0	Pennichuck Pond	all			
2001010	001	ROUND POND AND ROCHESTER RESERVOIR	Rochester	ROCHESTER WATER DEPARTMENT	7,196	386.59	11.2	53.0	Rochester Res.	all	all	all	
1191010	001	BEAR POND	Warner	CONTOOCOOK VILLAGE PRECINCT	759	386.35	1.2	49.0	Bear Pond	all	all	all	
1071010	001	HANOVER RESERVOIRS	Hanover	HANOVER WATER WORKS COMPANY	1,688	386.32	2.6	43.0	Lower Hanover	all	all	all	
1071010	001	HANOVER RESERVOIRS	Hanover	HANOVER WATER WORKS COMPANY	1,688	386.32	2.6	39.0	Upper Hanover	all	all	all	
1911010	001	BERRY POND	Pittsfield	PITTSFIELD AQUEDUCT COMPANY	754	386.57	1.2	37.0	Berry Pond	all			
1241010	005	BABBIDGE POND RESERVOIR	Roxbury	KEENE WATER DEPARTMENT	3,594	386.36	5.6	34.0	Babbidge Res	all	all	all	
1071010	001	HANOVER RESERVOIRS	Hanover	HANOVER WATER WORKS COMPANY	1,688	386.32	2.6	31.0	Hanover Center	all	all	all	
1691010	001	MOUNTAIN POND/GORDON HILL	New Hampton	NEW HAMPTON VILLAGE PRECINCT	595	386.52	0.9	24.0	Mt. Pond	all	all	all	
1621010	002	HARRIS POND	Nashua	PENNICHUCK WATER WORKS	16,247	386.50	25.4	23.0	Holt Pond	all			
0461010	004	WHITE WATER	Claremont	CLAREMONT WATER DEPARTMENT	2,940	386.19	4.6	18.0	Whitewater Res.	all	all	all	
1621010	005	SUPPLY POND	Nashua	PENNICHUCK WATER WORKS	16,920	386.50	26.4	16.0	Supply Pond	all			
0231010	001	AMMONOOSUC RIVER	Berlin	BERLIN WATER WORKS	16,000	386.14	25.0	10.0	Godfrey dam res	all res.			
0911010	003	WHITTLE BROOK RESERVOIR	Goffstown	GOFFSTOWN VILLAGE PRECINC	287	386.27	0.4	7.0	Goffstown Res	all			
1691010	001	MOUNTAIN POND/GORDON HILL	New Hampton	NEW HAMPTON VILLAGE PRECINCT	595	386.52	0.9	1.8	Gordon Hill Res.	all	all	all	

32

SUBTOT 32 28/32 = NO SWIM

										NOSwim	NOBoat	NOBath
1731010	002	FOLLETT'S BROOK	Newmarket	NEWMARKET WATER WORKS	1,020	386.53	1.6	0.9	Follet Brook	all		
2361010	001	FASSETT BROOK IMPOUNDMENT	Jaffrey	TROY WATER WORKS	716	386.68	1.1	0.5	Fasset Br. Res	all	all	all
1381010	001	NORTH GALE RIVER	Bethlehem	LITTLETON WATER & LIGHT DEPT	5,232	386.45	8.2		river	all		
1381010	003	GALE RIVER, SOUTH BRANCH	Bethlehem	LITTLETON WATER & LIGHT DEPT	5,379	386.46	8.4		river	see MOU		
0161010	001	ALBANY RIVER	Bartlett	BARTLETT VILLAGE PRECINCT	3,292	386.13	5.1		brook	all		
1291010	001	GARLAND BROOK	Lancaster	LANCASTER WATER DEPARTMENT	6,941	386.38	10.8		brook	all		
2001010	001	BERRY RIVER	Strafford	ROCHESTER WATER DEPARTMENT	8,285	386.60	12.9		Berry R & tribs	all	all	all
0151010	001	SWAIN'S LAKE	Barrington	SWAIN'S LAKE WATER DISTRICT	1,561		2.4					
0241010	001	GALE RIVER	Franconia	BETHLEHEM VILLAGE DISTRICT	2,060		3.2					
0241010	002	ZEALAND RIVER	Bethlehem	BETHLEHEM VILLAGE DISTRICT	4,962		7.8					
0461010	006	SUGAR RIVER	Claremont	CLAREMONT WATER DEPARTMENT	161,708		252.7					
0461010	007	DOLE RESERVOIR	Claremont	CLAREMONT WATER DEPARTMENT	58	386.19	0.1					
0461010	008	RICE RESERVOIR	Claremont	CLAREMONT WATER DEPARTMENT	118	386.19	0.2					
0501010	003	CONTOOCOOK RIVER	Concord	CITY OF CONCORD	173,451		271.0					
0691010	002	OYSTER RIVER-RES.	Durham	UNH/DURHAM WATER SYSTEMS	11,569		18.1					
0691010	003	LAMPREY RIVER	Durham	UNH/DURHAM WATER SYSTEMS	118,940		185.8					
0801010	002	DEARBORN BR. & RES.	Exeter	EXETER WATER DEPARTMENT	1,713		2.7					
0801010	003	EXETER RIVER	Exeter	EXETER WATER DEPARTMENT	58,158		90.9					
0921010	003	ICY GULCH	Randolph	GORHAM WATER & SEWER DEPT	1,117		1.7					
0921010	004	PERKINS BROOK	Gorham	GORHAM WATER & SEWER DEPT	2,640		4.1					
1061010	001	JUGGERNAUT POND	Hancock	HANCOCK WATER WORKS	156		0.2					
1101040	003	AMMONOOSUC RIVER	Haverhill	WOODSVILLE WATER & LIGHT	258,000		403.1					
1211010	004	ELLIS RIVER	Jackson	JACKSON VILLAGE PRECINCT			0.0					
1211010	001	MESERVE BROOK		JACKSON VILLAGE PRECINCT			0.0					
1321010	002	MASCOMA RIVER	Lebanon	LEBANON WATER DEPT	108,600		169.7					
1351010	002	LOON POND BROOK RESERVOIR	Lincoln	LINCOLN WATER WORKS	603		0.9					
1351010	006	EAST BRANCH OF PEMIGEWASS	Lincoln	LINCOLN WATER WORKS	73,950		115.5					
1621010	004	MERRIMACK RIVER	Merrimack	PENNICHUCK WATER WORKS	2,186,570		3416.5					
1731010	003	LAMPREY RIVER	Newmarket	NEWMARKET WATER WORKS	136,066		212.6					
1731010	004	PISCASSIC RIVER	Newmarket	NEWMARKET WATER WORKS	15,115		23.6					
2051010	010	ARLINGTON MILL RESERVOIR	Salem	SALEM WATER DEPARTMENT	15,400		24.1					
2151010	007	SALMON FALLS	Somersworth	SOMERSWORTH WATER WORKS	92,763		144.9					
2494010	009	PARTRIDGE BROOK	Westmoreland	CHESHIRE COUNTY HOME	15,394		24.1					
2494010	007	CONNECTICUT RIVER	Westmoreland	CHESHIRE COUNTY HOME	1,604,409		2506.9					

P1 SUBTOT 32 28/32 NOSWIM
P2 SUBTOT 34 7/34
TOT 66 35/66 = NOSWIM

Exhibit 4

TOWN of SALEM
NEW HAMPSHIRE

33 GEREMONTY DRIVE $ SALEM, NH $ 03079
603/890-2120 $ FAX: 603/890-2220

March 14, 2002

Mr. Harry Stewart, P.E.
Director of Water Division
Department of Environmental Services
New Hampshire Department of Environmental Services
6 Hazen Drive
P.O. Box 95
Concord, New Hampshire 03302-0095

RECEIVED
MAR 15 2002
DEPARTMENT OF
ENVIRONMENTAL SERVICES

Re: Drought Emergency
Planned Activities
Salem, New Hampshire

Dear Mr. Stewart:

Thank you for meeting with me, my staff and our consultants on Tuesday, March 12, 2002, to discuss our planned activities to proactively manage the drought emergency the Town of Salem, New Hampshire and all of New England currently find themselves in. At your request, we have prepared this letter to advise you of our planned activities and to seek your support and guidance in this most serious matter. This letter has been arranged in a series of subject headings to essentially document the discussions we had on March 12, 2002, and to clearly articulate the actions we have taken and those we propose to take in the short-term.

Current Situation

The Town of Salem, like many other New England communities, finds itself in a situation where we are very concerned about our ability to meet the demands placed on our water system for the remainder of this year and, potentially, beyond if the current drought conditions continue. Referring to Figure 1 attached, you will note that Canobie Lake was at overflow elevation approximately one year ago. Through the Spring and Summer of 2001, the lake elevation followed a very predictable pattern of dropping approximately three feet to approximately elevation 217 mean sea level (MSL). In years past, since the addition of the Arlington Pond supply source, Canobie Lake would naturally recharge to overflow elevation by being taken off-line between mid-October and late April of each year.

As can be seen from Figure 1, due to the extreme drought conditions, the actual lake levels are following a pattern much more reflective of a drought of record predictive simulation. The lake reached a "low" elevation of 215.65 MSL last November. Despite being taken off-line since October 2001, the lake has gained approximately one (1) foot of elevation since that time. Furthermore, and most alarming, we have completed simulations of what may occur for the remainder of 2002 if demands are reflective of recent history and the "drought of record" conditions continue. If these predictive assumptions are correct, the Town of Salem could find themselves in a situation of Canobie Lake dropping to an elevation of approximately 211.8 MSL, or less than approximately 1.2 feet above the intake by the September/October 2002 time frame. This provides less than 40 days of supply at that elevation (refer to Figure 2). Clearly, we, as public officials, cannot knowingly put the Town into this precarious situation.

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603/890-2120 $ FAX: 603/890-2220

Measures Taken To Date

On Monday, March 4, 2002, the Salem Board of Selectmen, acting in their capacity as Water Commissioners, unanimously voted to declare a state of drought emergency. This action is consistent with the Water System Management Plan the Town adopted on April 3, 2000 (see Exhibit 1). The immediate effect of this action is to institute mandatory demand management measures, including the banning of all outdoor water uses. The primary goal is to maintain current demand levels of approximately 2.0 million gallons per day (MGD) (monthly average) throughout this summer when historically they have increased to 3.0 to 3.3 MGD (monthly average).

Additionally, the Town will soon institute a system-wide leak detection survey. Currently, water that is unaccounted for represents approximately 14.5 percent of total demand. It is our goal to reduce the unaccounted for water to approximately 10 percent. If successful, we anticipate an average reduction of about 100,000 gallons per day (GPD).

We are also about to embark on an aggressive water conservation and public awareness campaign utilizing the elementary/middle schools in the Town as an effective means of getting the message out to the water supply consumers in the community.

Proposed Measures To Be Taken

As stated, it is our plan to utilize the existing infrastructure constructed in 1996/1997 as part of the Arlington Pond pipeline project to transfer water directly from Arlington Pond to Canobie Lake. Specifically, we propose to transfer 100 million gallons of water to Canobie Lake prior to April 30, 2002. Should a heavy rainfall occur during the approximate 30-day transfer period, the transfer will cease if Canobie Lake reaches elevation 218.0 before the full amount is transferred. The alternatives that were considered, as well as the protocol we intend to follow during this transfer, are described in detail in subsequent sections of this letter.

Alternatives Considered

Fully acknowledging the gravity of this situation, we have thoughtfully considered several alternatives to our planned action. Each is described below, and the technical and legal issues we considered are presented for your information.

Water Purchase From Town of Methuen—The Town of Salem currently has two intermunicipal connections with the Town of Methuen, Massachusetts. The combined hydraulic capacity is approximately 1 MGD, depending upon favorable hydraulic gradients in the two distribution systems. Of more relevance is that the standing intermunicipal agreement executed in 1993 (refer to Exhibit 2), does not assure the Town of Salem any amount of water. Simply put, the Town of Methuen has clearly indicated their intent of fully meeting their own needs as their first priority. No minimum notification period is required. Therefore, the Town of Salem must conclude that the Methuen connection cannot be reasonably relied upon when it is quite logical to assume that the Town of Methuen will be in a similarly stressed situation during the same period the Town of Salem would be looking for assistance.

Continued Reliance on Arlington Pond as Primary Source—The Town of Salem has entered into a legally binding agreement with the Arlington Pond Protective Association (refer to Exhibit 3) to manage the transfer of water from Arlington Pond to the Canobie Lake water treatment plant and/or directly to Canobie Lake. Key tenants of the agreements are as follows:

TOWN of SALEM
NEW HAMPSHIRE

33 GEREMONTY DRIVE $ SALEM, NH $ 03079
603/890-2120 $ FAX: 603/890-2220

A. Transfer will not be permitted between April 30 and October 10 of each year, unless the elevation of Arlington Pond exceeds 161.712 MSL.

B. Transfer will not be permitted between October 11 and April 29 of the following year, unless the elevation exceeds 154.5 MSL.

Since the transfer pipeline/booster station became operational in January 1997, this management plan has been closely followed, and has been quite successful in allowing Canobie Lake to naturally recharge to (or closely approach) overflow elevation annually by discontinuing the use of Canobie Lake and using Arlington Pond as the raw water source for the water treatment facility.

Continued transfer of water from Arlington Pond to the water treatment facility beyond the April 30 agreement date was considered under the assumption that Arlington Pond did not reach the 161.712 MSL level. However, this alternative is not considered viable for the following reasons:

A. This agreement was negotiated and drafted through a very public process, with particular debate and attention given to these critical dates and water elevations. It would be a clear violation of public trust to disregard this agreement at the first sign of a potential crisis.

B. Should the public trust be violated in this instance, a serious question of credibility would be created with current and future public officials in the Town of Salem who may be in similar situations of negotiating agreements or policies to implement future capital or infrastructure projects.

Delay Direct Transfer Until Canobie Lake Drops to Pre-Determined Elevation—An additional alternative considered was to delay a direct transfer of water from Arlington Pond to Canobie Lake until such time as a pre-determined critical lake level was reached. For discussion purposes, an elevation of 214.0 MSL could be deemed "critical" since the available remaining storage is just over 100 days of supply at that elevation.

The advantage of this strategy is the short-term avoidance of the direct transfer and attendant concerns of water quality degradation. It is possible that weather patterns may change which would negate the need for direct transfer in the short-term. This advantage, while somewhat attractive, is seriously outweighed by several factors:

A. Allowing Canobie Lake to drop to this critical stage will cause greater stress to litoral (shoreline) vegetation and the associated ecosystem.

B. The remaining storage volume in the lake will be subject to greater temperature rise, and will have less assimilative capacity should the direct transfer be required in mid to late Summer.

C. Most importantly, the water quality of Arlington Pond is known to degrade in the late Summer and early Fall. Higher color, bacteria and, potentially, nutrient load could reasonably be expected due to the relatively small amount of actual flow through the impoundment at this time of the year.

TOWN of SALEM

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603/890-2120 $ FAX: 603/890-2220

The net result of this delayed direct transfer alternative is the potential for discharge of water of poorer quality at a time when Canobie Lake is under greater stress with less assimilative capacity.

<u>Immediate Transfer in April 2002</u>—The final alternative considered is the immediate transfer of water from Arlington Pond to Canobie Lake during the month of April 2002. Specifically, a transfer of approximately 100 million gallons is planned, or until Canobie Lake reaches elevation 218.0 MSL through a combination of direct transfer and natural recharge aided by Spring runoff should appreciable rainfall occur during this time frame.

Proposed Sampling Program

From our many conversations with our consultants, the New Hampshire Department of Environmental Services (NHDES) and the United States Environmental Protection Agency (USEPA), we are aware of your regulatory constraints and water quality concerns associated with direct transfer. Therefore, we have developed a water quality monitoring program that we will implement during the period of direct transfer. The proposed sampling program is outlined below in Table 1.

Table 1
Water Quality Sampling Program

		SAMPLING LOCATIONS	
Parameter	**Frequency**	**Arlington Pond**	**Canobie Lake**
PH	Daily	WTP Sample tap[1]	Influent Streams[3]
Turbidity	Daily	WTP Sample tap[1]	Influent Streams[3]
Color	Daily	WTP Sample tap[1]	Influent Streams[3]
Total Coliform	3 times/week	WTP Sample tap[1]	Influent Streams[3]
E Coli Bacteria	3 times/week	WTP Sample tap[1]	Influent Streams[3]
Total Phosphorous	3 times/week	WTP Sample tap	Influent Streams[3]
Cabomba Caroliniana	Continuous[1]	WTP Sample tap[1]	Influent Streams[3]

Notes:

[1]A continuous flow stream of approximately 50 GPD will be sidestreamed to a filter apparatus in the laboratory to capture any particulate matter, including evidence of the *Cabomba Caroliniana* plant fragments or seeds. It is noted that prior trials of this filter system revealed no evidence of the *Cabomba Caroliniana* seeds or plant fragments.

[2]The Canobie Lake water treatment facility laboratory is equipped with a sample tap on the raw water transmission main where the Arlington Pond raw water can be sampled.

[3]Two small influent streams located in the Towns of Windham and Salem represent most of the indirect surface runoff to Canobie Lake.

We propose to collect all samples in accordance with the frequency outlined. All analysis will be done in our laboratory facilities under the direct supervision of William Daly, the facility's Chief Operator, except bacteria and phosphorous, which will be delivered to the state laboratory for analysis.

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NEW HAMPSHIRE

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603/890-2120 $ FAX: 603/890-2220

Short-Term and Long-Term Objectives

As stated, we plan to commence the direct transfer on or about April 1, 2002. We believe that it is prudent to take this measure as part of our overall demand and source management strategy to prevent a potentially significant crisis by this Summer if the drought continues. We also intend to work closely with your office to use this thirty (30) day transfer period as a pilot program to gather water quality data (outlined above) to begin to create a technical database from which we will formulate a longer-term strategy. As stated, it is our intention to seek regulatory approval to initiate direct transfers on an "as needed" basis to maximize the use and storage capability of our two major supplies of raw water.

I trust this letter outlining our alternatives analysis, steps taken and steps planned to be implemented has sufficiently addressed the issues raised at our March 12th meeting. I look forward to your continued understanding and support when we meet again on March 21, 2002 to finalize our plan.

Respectfully yours,

TOWN OF SALEM, NEW HAMPSHIRE

Jeffrey C. Towne
ZHK

Jeffrey C. Towne
Town Manager

Enclosure
JT:srd\I:\clients\salemNH\droughtemergencyplannedactivities_NHDES.doc

Cc: Board of Selectmen, Town of Salem, New Hampshire
Rodney Bartlett, Superintendent, Department of Public Works
William Daly, Operations Manager
Anthony J. Zuena, P.E., S E A Consultants Inc.
Raymond H. Korber, P.E., S E A Consultants Inc.

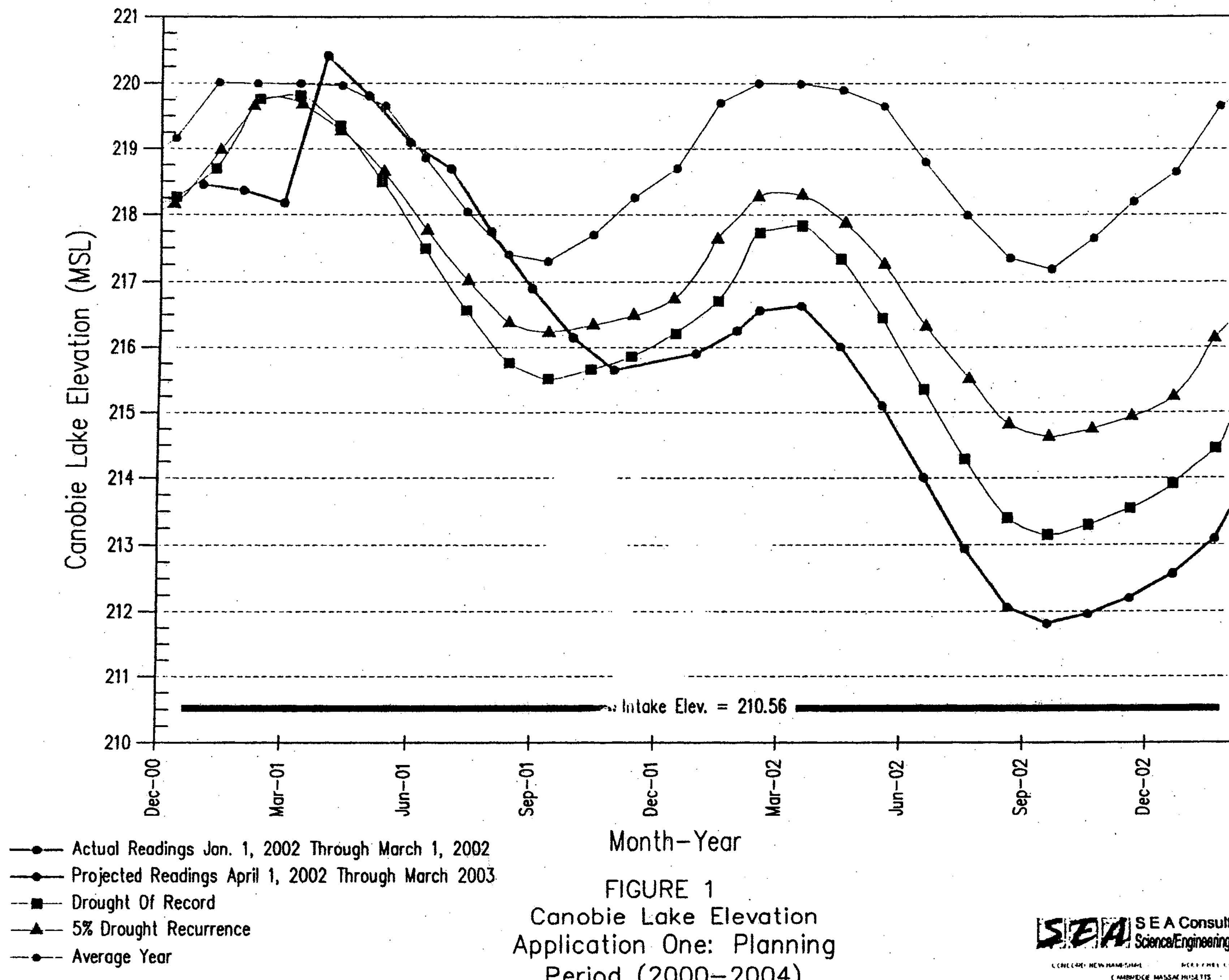


FIGURE 1
Canobie Lake Elevation
Application One: Planning
Period (2000–2004)

S E A Consultants Inc.
Science/Engineering/Architecture

Figure 2
Canobie Lake
Elevation / Storage / Days of Supply Relationships

Elevation (MSL)	Volume (Million Gallons)	Days of Supply
217	605	253
216	492	206
215	384	161
214	282	118
213	184	77
212	90	38
211	0	0

Notes:
Annual Average Day Demand = 2.39 MGD
Intake Elevation = 210.56

Town of Salem New Hampshire
Water Management Plan
Adopted by B.O.S. 4-3-2000

1. Canobie Lake actual level is to be compared against Canobie Lake Predicted Level from Figure 4.2 of the Comprehensive Source Development and Conservation plant for the Town of Salem, New Hampshire by SEA Consultants 1996. Figure 4.2 is to be used for the years 2000 through 2004. Later years are to come off of Figures 4.3, 4.4 and 4.5.

Actual Level is to be compared against predicted levels on the following dates.

DATE	PREDICTED LEVEL	VOLUNTARY RESTRICTIONS	MANDATORY RESTRICTIONS	DROUGHT EMERGENCY
APRIL 15	219.9	218.4	217.9	216.9
APRIL 30	219.6	218.1	217.6	216.6
MAY 15	219.4	217.9	217.4	216.4
MAY 30	219.0	217.5	217	216
JUNE 15	218.85	217.35	216.85	215.85
JUNE 30	218.75	217.25	216.75	215.75
JULY 15	218.55	217.05	216.55	215.55
JULY 30	218.35	216.85	216.35	215.35
AUG 15	218.15	216.65	216.15	215.15
AUG 30	217.95	216.45	215.95	214.95
SEPT 15	217.75	216.25	215.75	214.75

2. If the actual level falls below the predicted level, it will be compared against the levels triggering Voluntary Restrictions, Mandatory Restrictions and Drought Emergency Conditions. Appropriate action will be initiated by the Board of Selectmen.

3. These restrictions will take effect only when no transfer from Arlington Pond is possible.

Exhibit 5

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
6 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095
(603) 271-3503 FAX (603) 271-2982

April 3, 2002

Mr. Jeffrey Towne
Town Manager, Town of Salem
33 Geremonty Drive
Salem, New Hampshire 03079

SUBJECT: Request for Proposed Water Transfer from Arlington Pond to Canobie Lake

Dear Mr. Towne:

By letter dated March 14, 2002, the Town of Salem requested approval of the New Hampshire Department of Environmental Services (DES) to transfer a total of 100 million gallons of water during the month of April 2002, from Arlington Pond to Canobie Lake. Additional information and a formal request for emergency water transfer under Env-Ws 1710, DES's new emergency rules for emergency water transfer, were provided in a letter dated April 3, 2002 to Mr. Paul Currier of DES from Mr. Raymond Korber, P.E. of S E A Consultants, Inc. (SEA).

DES has also recently met with local officials on two occasions and attended a meeting of the Board of Selectmen on March 25, 2002 concerning this request. At the March 25 meeting, a presentation was made by SEA for the Town of Salem on the proposed transfer followed by questions and comments by the public.

Our decision and rationale are presented below. We have also proposed an alternative for your further consideration.

Decision

The temporary transfer of water from Arlington Pond to Canobie Lake is hereby approved, subject to the following conditions:

1. The transfer from Arlington Pond to Canobie Lake is limited to a cumulative total of 100 million gallons.

2. No transfers will occur after September 30, 2002.

3. The Water Quality Sampling Program described in Table 1 of the Town's March 14, 2002 letter must be implemented when transfers are occurring. Should sampling indicate seeds or plant fragment from the exotic species *Cabomba Caroliniana* (fanwort) have penetrated the screen or should other water quality degradation of Canobie Lake become evident during any phase of the transfer that is attributable to the transfer, the Town shall notify DES immediately and DES may require termination of the transfer operations.

4. This approval is terminated and no further transfers shall occur if the Town of Salem's drought emergency is terminated or the ban on outdoor water use and other water conservation measures are lifted.

5. The Town must comply with all conditions in the NPDES Permit Exclusion #02-065 dated April 3, 2002, as granted by the United Stated Environmental Protection Agency.

6. Salem must move forward expeditiously to resolve its long term water supply needs. A framework for this evaluation that includes consideration of surface water, groundwater and regional water supply alternatives must be submitted to DES within 30 days of this approval.

Discussion

In making this decision, we have considered the need for short term water supply as demonstrated by the Town and the actual or potential impacts of the proposed transfer on lake water quality and recreational interests on both Canobie Lake and Arlington Pond in the context of state and federal regulatory requirements. The following factors were considered by DES:

The need for the emergency water transfer has been established. The Town Board of Selectmen declared a drought emergency on March 4, 2002. On March 13, 2002, the State of New Hampshire Drought Management Team also declared a Drought Emergency for the entire state, except Coos County, under the state's drought management plan. This drought event has closely tracked, for a twelve month period, the 1960's drought of record which lasted about three years. While there have been several rainfall events since early March, New Hampshire will remain in a drought emergency condition unless significant precipitation occurs to make up for the deficit incurred over the last twelve months. The impacts on Salem's water supply are projected to be very significant, with less than 40 days supply projected to remain in Canobie Lake in September 2002, even with water conservation measures in place, should the drought continue. Furthermore, if the drought continues into 2003, conditions worsen with time and the system is projected to fail to have even minimum supply available in future years. The Town appropriately seeks to avoid this very severe condition.

2. ***The Town has implemented water conservation and demand management measures to reduce water use during the critical warm weather period.*** Salem has initiated an aggressive water conservation program to reduce water demand including a ban on outdoor water use to reduce peak demand, a leak detection program to reduce unaccounted for water and other measures including outreach to the community. If the drought emergency is lifted and water conservation requirements are relieved, no transfers will be allowed by DES under this approval.

3. ***The proposed emergency transfer is the only short term alternative that is predictably available to avoid a critical condition in Canobie Lake, should the drought event continue through the summer months, considering constraints in local agreements on***

other alternative sources. Other water supply sources in Salem's control are not available to avoid a critical condition in Canobie Lake during summer drought conditions, or in preparation for an extended drought. The Town of Salem's interconnection to the Methuen water supply system can physically supply about one million gallons per day (mgd); however, the intermunicipal agreement between Salem and Methuen contains a "Methuen first" clause which means that availability cannot reasonably be expected during a drought condition. Also, the availability of Salem's other primary water supply source, Arlington Pond, is limited by a written agreement between the Town and the Arlington Pond Protective Association (APPA) under which the Town cannot use Arlington Pond between April 30 and October 10, unless the water level exceeds 161.712 MSL, which is highly unlikely during a drought event. Consequently, transferring water to augment storage in Canobie Lake is the only alternative that enables Salem to predictably minimize the potential for a critical water supply shortage later in 2002 and into 2003. Note that DES has approved this transfer over a six month period up to the requested total volume of 100 million gallons per day rather than the requested 30 day period. This is intended to enable Salem to spread the withdrawal over time to hedge for the potential that rainfall events will occur and the drought condition will diminish, reducing the need for transfers, with no greater impact on Arlington Pond, if the APPA is willing to amend its agreement with the Town.

4. ***DES has reviewed the available information and concluded that the source water meets applicable water quality standards, and the receiving water will continue to meet applicable water quality standards during and after the transfer is completed.***

   Three water quality parameters of primary concern have been identified and considered in this decision:

   a. Phosphorous is present at similar concentrations in Arlington Pond and Canobie Lake. Consequently, phosphorus concentrations in Canobie Lake will not change significantly should a short term transfer of up to 100 million gallons occur. DES also estimates that less than 20 pounds of phosphorus would be contributed to Canobie Lake by a transfer of up to 100 million gallons. This is not a significant contribution to the overall phosphorus loading on Canobie Lake.

   b. The exotic plant species, *Cabomba Caroliniana* (fanwort), is present in Arlington Pond but not in Canobie Lake. The Town has reasonably mitigated the potential for the transfer of fanwort from Arlington Pond to Canobie Lake by installation of drum screens at the intake in Arlington Pond. These screens have been specifically designed to screen out fanwort seeds or plant fragments at Arlington Pond.

   c. Arlington Pond water consistently has higher color, which is an aesthetic concern, than Canobie Lake water. The proposed discharge of 100 million gallons, with dilution in Canobie Lake, should not have a discernable impact on the lake's water quality.

Additionally, Arlington Pond meets a primary test for discharge to Class A waters under Env-Ws 1710, Emergency Water Transfers, and a criteria for Class A under RSA 485-A:8: "There shall be no discharge of sewage or wastes into waters of this classification." Under RSA 485-A:8, Class A waters are in part those waters that are "potentially acceptable for water supply users after adequate treatment." Arlington Pond is a public water supply source and its water receives the identical treatment as Canobie Lake water. Considering these factors, Canobie Lake's classification as a Class A water body will not be affected by a water transfer from Arlington Pond.

Possible Alternative to the Proposed Transfer

DES has approved the Town's request to transfer water from Arlington Pond to Canobie Lake considering the existing drought emergency, and in recognition of the existing constraints imposed on the Town by existing agreements with the Town of Methuen and the APPA. However, considering the public comment at the Selectmen's meeting on March 25, irrespective of DES's conclusions relative to the potential impacts of a transfer, we also recognize that the direct transfer of water from Arlington Pond to Canobie Lake will raise significant concerns with some members of the public due to the perception of potential impacts. In this context, we propose an alternative for your consideration that would enable Town to achieve its stated goal, if some existing constraints can be clarified or loosened.

In essence, the Town's objective for 2002 is to increase water supply capacity by 100 million gallons from April 30 to October 10, when the only available, predictable supply is Canobie Lake. An alternative that would attain equivalent results to the proposed transfer follows:

Obtain as much water as possible from Methuen, beginning in April, because this source may be available now but is not likely to be available during the summer months if the drought persists. When available, using Methuen to the maximum allowable extent will preserve water in reservoir storage, considering Canobie Lake and Arlington Pond collectively, that is under the direct control of Salem for future use. At maximum transfer rates, this could preserve up to one million gallons per day of water in storage in Salem's reservoirs for future use.

2. Extend the use of Arlington Pond as the primary water supply source beyond April 30. Whether the authorized transfer of an additional 100 million gallons occurs in about a 25 day window through April 30, as currently proposed by the Town, or spread over 60 to 90 days at 1 or 2 million gallons per day makes no difference in Arlington Pond since the ultimate impact on lake volume and water elevation is the same. Furthermore, spreading the withdrawal time hedges for the potential that rainfall events will occur at rates that equal or exceed normal, thus diminishing drought conditions and reducing or alleviating the need for transfers. We fully recognize the recreational demands on Arlington Pond and suggest that that the Town and APPA consider alternative solutions not considered by the existing agreement during this emergency drought condition.

While our decision to approve the proposed transfer recognizes the existing constraints on the Town of Salem, we urge you to give serious consideration to this possible alternative approach, or similar approaches, which minimize the need for the transfer.

Please be advised that this decision may be appealed to the New Hampshire Water Council ("Water Council") by filing an appeal to the Water Council that meets the requirements specified in the Procedural Rules of the Water Council, Env-WC 200, within 30 days of the date of this Decision. Copies of Env-Wc 200 are available from the DES Public Information Center at (603) 271-2975 or at http://www/state.nh.us/desadmin.htm.

We are available at your request to meet to further discuss this decision or Salem's plans to resolve its long term water supply requirements.

Sincerely,

Harry T. Stewart, P.E.
Director, Water Division

cc: Anthony P. Giunta, P.G., NHDES
Paul Currier, P.E., NHDES
Rodney Bartlett, Superintendent, Salem Department of Public Works
Raymond Korber, S E A Consultants, Inc.

Exhibit 6

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
NHDES
6 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095
(603) 271-3503 FAX (603) 271-2867

STATE OF NEW HAMPSHIRE

WATER COUNCIL

Decision & Order

Docket No. 01-20 WC
Appeal of John Dixon *et al.*
In Re: Request for Waiver of Env-Ws 386.64(h)(5)

By Request for Waiver dated August 1, 2001, John Dixon and other owners of property abutting Lake Sunapee within ¼-mile of the intake for the Sunapee public water system requested a waiver of Env-Ws 386.64(h)(5) to allow swimming within 100 feet of the shoreline within the no-swim zone. That rule states that "[n]o person shall bathe in [Lake Sunapee] within one fourth mile of where water is taken for a public supply, or within like distance to any private intake pipe, provided notice to that effect is conspicuously posted in the vicinity[.]"

By letter dated October 19, 2001, the Department of Environmental Services, Water Division denied the requested waiver on the basis that granting it "would contravene the intent of the rule", which is "to prevent the contamination of the water supply with pathogenic organisms (such as bacteria, viruses, or protozoans) from the feces, bodily fluids, or skin of any bather, as well as to minimize the turbidity of the source water by minimizing the stirring up of sediment near the shore." John Dixon and the others who requested the waiver filed an appeal with the Water Council dated November 13, 2001. The appeal was accepted by the Council and was assigned Docket No. 01-20 WC.

Under the authority of RSA 21-O:7 and RSA 21-O:14, a hearing before the Council was held on Wednesday, August 21, 2002 beginning at approximately 10:00 a.m. at the Department's offices in Concord. The hearing was conducted in accordance with RSA 541-A:31-38 and the Council's procedural rules, NH CODE ADMIN. RULES Env-WC 200.

At the hearing, the Council heard testimony and received evidence relative to the denial of the requested waiver. Testimony and evidence also was presented relative to Mr. Dixon's alternative theory that the "no bathing" rule does not prohibit swimming. The evidence demonstrated that while Env-Ws 386.64(h)(5) has been in effect for a number of years, there has been no enforcement of the rule. Due to the lack of enforcement, the property owners who live within the no-swim zone have been swimming in front of their property for years with no problems. The value of their property would be severely affected by any sudden enforcement, causing a real and measurable hardship. The evidence further revealed that while the rule requires adequate signage as to the no-swimming requirement, there is only one sign that is located at the town dock. There are no additional signs along the shoreline within the no-swim zone.

With regard to the impact of the swimmers on the quality of the water supply for the town, evidence was presented that there is now a sand filtration system in place to purify the water that was not in place when the rule was adopted.

Env-Ws 386.04(b) provides in relevant part,

(3) The division shall approve a request for a waiver upon finding that:

a. The proposal shall be at least equivalent to the specific requirement contained in the rule; or

b. If the proposal was not equivalent to the requirement contained in the rule, it shall be adequate to ensure that the intent of RSA 485:24 and RSA 485:25 is met.

Based on the evidence detailed above, the Council concludes that the Department acted in an arbitrary and capricious manner by not granting the requested waiver. Where there has been no enforcement of the no-swim zone (including inadequate signage), and a sand filtration system has been put in place to purify the water, the Council finds that a waiver to allow property owners to swim within 100 feet of the shoreline within the no-swim zone would be adequate to ensure that the intent of RSA 485:24 and RSA 485:25 is met. The appeal of John Dixon *et al.* is therefore **GRANTED**.

Pursuant to Env-WC 203.29(a), any person whose rights might be directly affected by this decision may file a motion for rehearing within 30 days of the date of this decision. The motion must contain the information specified in Env-WC 203.29(b). Copies of any motion for rehearing shall also be sent or delivered to all other parties of record. Pursuant to Env-WC 203.29(e), this decision shall become final if no motion for rehearing is filed within 30 days.

Dated: Jan. 24, 2003. So Ordered for The Council: F. Wayne DiMarzio - by MPS
F. Wayne DiMarzio, Vice Chairman

COPY

Exhibit 7

MANDATE
Certified and Issued as Man[illegible]
Under N.H. Sup. Ct. R. 2[illegible]
COPY
Clerk/Deputy Clerk
Date: 6/7/04

THE STATE OF NEW HAMPSHIRE

SUPREME COURT

In Case No. 2003-0382, <u>Appeal of New Hampshire Department of Environmental Services</u>, the court on May 20, 2004, issued the following order:

Having considered the record on appeal and the briefs and oral arguments of the parties, the court concludes that a written opinion is not necessary for the disposition of this appeal. The New Hampshire Department of Environmental Services (DES) appeals the order of the New Hampshire Water Council (Council) reversing its decision to deny the petitioners, homeowners on Lake Sunapee, a waiver of the no-swim rule, which prohibits swimming within ¼ of a mile of a public drinking water supply intake. <u>See</u> <u>N.H. Admin. Rules</u>, Env-WS 386.04, 386.64(h)(5). We affirm.

We will not set aside the Council's decision on appeal unless we are satisfied by a clear preponderance of the evidence that its decision was erroneous as a matter of law, unjust or unreasonable. <u>See</u> <u>Appeal of Comm. to Save the Upper Androscoggin</u>, 124 N.H. 17, 26 (1983); RSA 541:13 (1997).

DES assigns two errors to the Council's decision. DES first argues that the Council improperly applied the legal doctrine of municipal estoppel. We do not share DES' interpretation of the Council's decision. We find no reference to that doctrine in its decision. Instead, we believe that, as required, the Council examined whether DES acted either contrary to State law or arbitrarily and capriciously. <u>See</u> <u>N.H. Admin. Rules</u>, Env-WC 203.16.

DES found that to grant the waiver would be inadequate to ensure the purity of the water. <u>See</u> RSA 485:24, :25 (2001); <u>N.H. Admin. Rules</u>, Env-WS 386.04(b)(3)b, 386.04(c). DES found that protecting the purity of the water required both filtration and the no-swim rule. Hence, DES reasoned, it could not grant the waiver without dismantling this multi-barrier approach to water supply protection.

The Council found, however, that DES has no such multi-barrier approach at Lake Sunapee. The Council found that, contrary to DES' assertions, the no-swim rule had not been enforced. Because of this, property owners had been swimming in the no-swim zone for many years "with no problems." Given this, the Council ruled that the Lake's single barrier to water contamination, a sand filtration system, was adequate to ensure water purity. The Council thus ruled that DES acted arbitrarily and capriciously when it denied the waiver request.

In Case No. 2003-0382, Appeal of New Hampshire Department of Environmental Services, the court on May 20, 2004, issued the following order:

DES next argues that the Council's decision is flawed because it does not contain sufficient factual findings. See RSA 541-A:35 (Supp. 2003). We disagree. The Council's explanations in support of its factual findings satisfy the requirement that it "include specific, although not excessively detailed, basic findings in support of [its] ultimate conclusions." Appeal of City of Nashua, 138 N.H. 261, 264 (1994) (quotation omitted). Moreover, although there is no transcript of the Council's hearing, DES previously represented that the existing record was adequate to permit appellate review. Accordingly, it may not now argue directly or indirectly that there is insufficient evidence to support the Council's decision. See Brown v. Cathay Island, Inc., 125 N.H. 112, 115 (1984); Sup. Ct. R. 13, 15.

Affirmed.

BRODERICK, NADEAU, DALIANIS, DUGGAN and GALWAY, JJ., concurred.

Distribution:
NH Department of Environmental Services 01-20 WC
Amy B. Mills, Esquire
Willian D. Pandolph, Esquire
James Q. Shirley, Esquire
Irene Dalbec, Supreme Court
Case Manager
File

Exhibit 8

Steve Andrews

From: DICKHATA@aol.com
Sent: Thursday, November 17, 2005 6:24 PM
To: JCARPO@aol.com; Steve Andrews
Subject: Re: Waver Request Env-Ws 386.61 (h)(4) Canobie Lake No SwinRule

Hi John & Steve:

I happened to be in Concord today talking with Harry Stewart today regarding other matters when he mentioned that he received a petition from two residents of Canobie Lake regarding the no-swim Rule. He gave me a copy of the petition.

Frankly I was flabbergasted! I wish you had at least called me or one the other association directors to discuss your thoughts first.

We, as an association cannot tell anyone what to do or think, however we can give you a bit of history regarding the reason folks move onto Canobie Lake as opposed to recreational lakes. Most move here specifically because of the tranquility and its bit of wilderness so close to civilization.

Since the early 1960's there have been several votes by association members on whether they want swimming on the lake with all that it entails. The overwhelming majority of residents have repeatedly voted not to change the way things are.

Before discussing that, ask someone who lives on Cobbetts Pond or Arlington Pond what a Saturday or Sunday on their lake is like. Even every night of the week during the summer there are two & four person jet skis, high speed boats with water skiers are constantly bounding around the lake, the noise is constant.

kayakers, canoes and pontoons are being rocked about all the time. The shoreline and docks are always in motion, turbidity and erosion are bi- products of this activity. You can't hear yourself talk or think on those lakes!

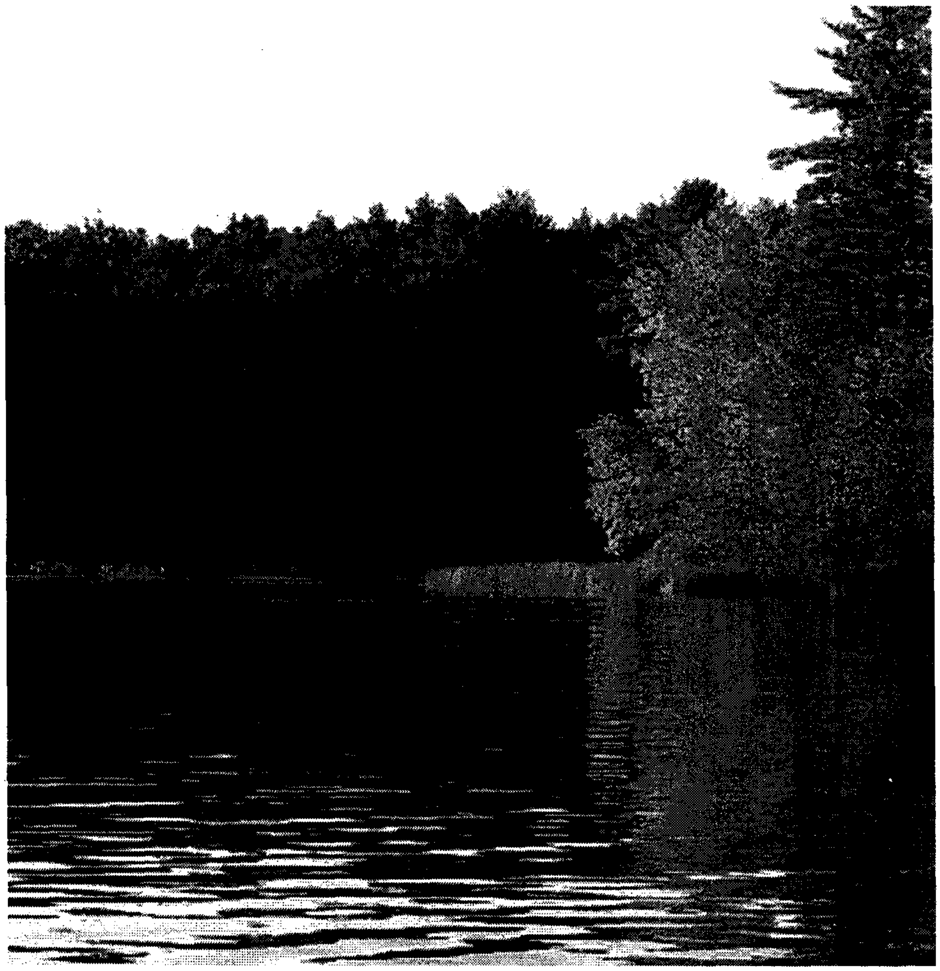
It is mentioned in the petition that there is no enforcement to the No-Swim Rule. That's a bit off. We association members do the enforcement. Certainly there are always new residents who go onto the lake and fall off their boats and swim or those who swim next to their docks. However, when things get out of hand we have a talk with them and they are more compliant and understanding of what's more important to the values of living in this environment. Sometimes they even tube around a few times until they get it!

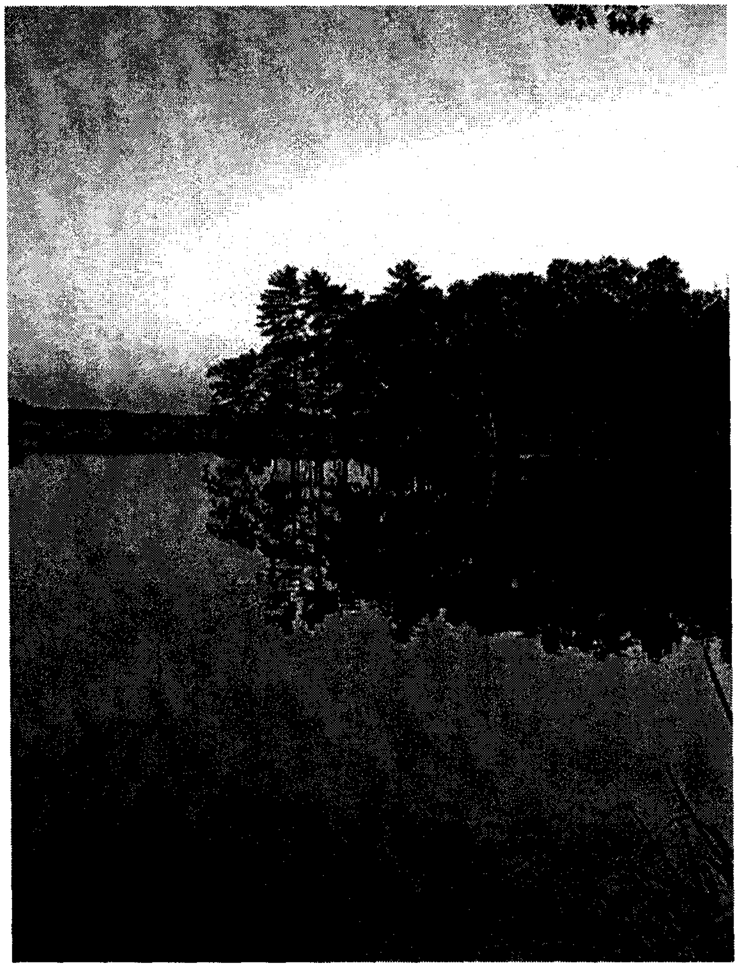
It doesn't get much better than this, anywhere!

If swimming were to be allowed the very nature of the lake would change. Do you really want that? Everything mentioned regarding Cobbetts and Arlington Ponds will happen here. The jet ski ban we passed several years ago was based on bodily contact in a municipal water supply. Water skiing would then be allowed with very high speed boats. The association could then petition for a speed limit on the lake. 5 mph.

Property values: Do think it's arguable that your homes would be more valuable on Arlington or Cobbetts rather that here? To begin with you couldn't find homes like yours on those lakes. There's a home nearly finished now on South Shore Road, on the lake, in Salem on a 37' wide x 200' deep lot. The home is 20' wide x 50' deep and is listed in the paper for $750,000. How's that for value?

You could not sit out in the evening and have dinner and drinks without the roar of motors drowning out your conversation.





Neither of those other lakes have marshes or wetlands or loons, or a ***Heron Cove.*** The loons most likely would leave the lake due to all the traffic.

John, you have a pool why do you want to swim in the lake? Perhaps you or your son want to want to water ski! Maybe you don't mind a pontoon boat anchored in front of your home full of kids swimming all afternoon?

Steve, I've lived here for 36 years and brought up four children on the lake. We did swim and tube but got it out of our systems after a season. Then we built a pool.

What your talking about here is having 60 pontoon boats out on the lake with people diving off them every weekend. Do you really want that? Then, add the water skiers to the mix. Then, there's the jet skis!

The folks who lived here before us were tolerant of our misbehavior but realized that we too would begin to understand the value and respect this lake deserves.

It's not so much about swimming, as it is about what comes with it!
Jet skis, Water skis, Hi speed boats, Noise, Turbidity, Erosion, Privacy, Dock movement, Loss of peace & quiet, Water pollution, e.Coli, Property

values, Etc.

Let's talk about it, we've got it made here, let's find a way to work this out.

Sincerely.

Dick Hannon

Exhibit 9

Steve Andrews

From: WESchro721@aol.com
Sent: Saturday, November 19, 2005 11:41 AM
To: DICKHATA@aol.com; CanobieQue@aol.com; Steve Andrews; JCARPO@aol.com
Subject: Re: Meeting Sunday

Hello Steve, John, Dick and Betty:

I'm sorry I won't be able to make it on Sunday at 1 PM. I have a prior commitment for that morning and afternoon.

But I do share Dick's concern about the petition to allow swimming. I hope that you will consider withdrawing it. I'm sure Dick and Betty can go over the lake use history, and the likely scenarios in the future.

First, if you want to go swimming off your lake front property I wouldn't report it, and I doubt if any of your neighbors would either. But if the ban is officially removed, there's nothing to stop water skiing and I believe that would soon follow. That, in turn, would encourage people who don't presently come to the lake to bring their ski boats here and i don't think there would be any effective way to stop that.

So I'm concerned that the quiet nature of the lake would be adversely and irreversibly changed.

I'm sorry I won't be able to be at the meeting, because I would like to hear your point of view, too.

Best wishes,

Bill Schroeder

Phone/FAX: 603-898-6086
email: weschroeder@ieee.org

Exhibit 10

Exhibit 10
Comments to NHDES Discussion Points in Denial Letter of March 9, 2006

FORMAT: A paraphrase of the NHDES position appears in underlined italics; the response by the Appellants follows in standard type.

1. *NHDES states that the purpose of Env-Ws 386.01 is to "...provide methods for* ***reasonable*** *[emphasis added] watershed management so as to maintain high levels of water quality."*

   It is **unreasonable** to permit direct water transfers from Arlington Pond [swimming permitted] into Canobie Lake while simultaneously forbidding swimming by Canobie residents.

2. *History shows that swimming in Canobie has been restricted since 1903.*

   Sanitation at the turn of the century was much different than today. Consider:
   a. Drinking water was not treated.
   b. Raw sewage was routinely emptied into lakes and rivers .
   c. Only 1 in 7 houses had bathtubs.
   d. Typhoid was a very real threat and was believed to have caused 35,000 deaths in 1900 alone (*Exhibit 15*).
   e. The average life expectancy was 49 years.
   f. The *Bubonic Plague* erupted in San Francisco.

   Modern improvements in general sanitation combined with advancements in water treatment actually support the position that the intent of RSA 485:24 and RSA 485:25 is met by the Waiver. The provision dates back to the turn of the century and was enacted under very different circumstances. The intent of RSA 485:24 and RSA 485:25 was never to arbitrarily prohibit swimming.

3. *NEWWA policy supports multiple barrier protection of drinking water supplies and prevention of body contact.*

   No such barriers exist as it pertains to swimming in Canobie Lake. Witness:
   a. NHDES approved of, and Salem initiated a direct water transfer from Arlington Pond [swimming permitted] into Canobie Lake in 2002 (Exhibits 4 &5).
   b. Residents are known to swim dockside (*Exhibit 8, page 1*).

4. *AWWA warns of Recreational Use of Domestic Water Supply Reservoirs.*

   a. Boating is currently permitted on Canobie Lake.
   b. Some form of recreation is permitted in 64% of all surface source water bodies in the state; swimming is permitted in 47% (*Exhibit 3*). There has been no commensurate collapse of the state water supply system.

c. Residents are known to swim dockside in Canobie Lake without incident (*Exhibit 8, page 1*).

5. *USEPA supports a multiple barrier approach for water supply protection.*

   a. By the Department's own actions in approving a direct water transfer in 2002, no such barriers exist as it pertains to swimming in Canobie Lake. (See point #3).
   b. The Safe Drinking Water Act cited by the Department, does not encourage, suggest or imply that swimming should be banned as part of drinking water protection measures.

6. *Body contact recreation increases the risk of contamination.*

   a. By the Department's own action, it approved direct water transfer from Arlington Pond.
   b. The Department dismisses the swimming contamination risk as 'marginal' when discussing Arlington Pond (*see discussion point 10 in the Denial Letter, Exhibit 1*).
   c. Residents are known to swim dockside in Canobie Lake without incident *(Exhibit 8, page 1*).
   d. The two studies (Stewart and Anderson: *Exhibits 11 &12*) cited by the Department are actually a single study published twice under two different authors. It examines completely different circumstances. The cited study models contamination of a reservoir from the recreational activity of **over 600,000 people** in Southern California (Exhibit 11, Page 89, Table 3). By contrast, there are only 80 homes on Canobie Lake, and no public beach. At an average household size of 2.7, that translates into a total of just 216 people. It is intellectually dishonest to cite such a study and claim any relevance to Canobie Lake.

7. *The Stewart and Anderson studies indicate that the waiver application fails to meet the intent of RSA 485.24.*

   a. It is intellectually dishonest to suggest that a model of body contact contamination in Southern California by 600,000 people can be compared to Canobie Lake with a shoreline population of 216 +/-.
   b. In 2002, the Water Council found that the addition and presence of a sand filtration plant was sufficient to meet the intent of RSA 485.24 and RSA 485.25 (*Exhibit 6*). Salem built a state of the art plant in 1995 that treats and filters both Arlington Pond Water and Canobie water with advanced processes.
   c. See point 6d above.

8. *The swimming prohibition [and therefore the denial] is consistent with best management practices in the water industry.*

a. If so, then it is inconsistent with the Department's own actions and policy of approving direct water transfers from Arlington Pond.
b. The Department cannot maintain that direct water transfers from Arlington Pond are 'safe', act on that belief, and then proceed to argue that swimming by shoreline residents is dangerous.
c. The Safe Drinking Water Act forged by the USEPA does not encourage, suggest or imply that swimming should be banned as part of drinking water protection measures.

9. *Other source water lakes in New Hampshire also have "no-swim" restrictions.*

a. The corollary is that swimming ***is permitted*** in nearly half of the surface source water bodies in New Hampshire *(Exhibit 3).* The restriction is arbitrarily assigned as the result of 100 year old legislation.
b. Further, no other surface water sources within the state can point to:
   i. another water body within the water system, treated by the same plant in which swimming is permitted
   ii. evidence of direct water transfer between a swimming permitted source into a swimming prohibited source.

10. *Too rambling to paraphrase.*

a. The transfer of water from Arlington Pond into Canobie Lake occurred in the summer of 2002.
b. Any hypothetical Cryptosporidium outbreak is far more likely to come from Arlington Pond than Canobie Lake (*Exhibit 13*).

11. *The fact that swimming is permitted in other source water bodies does not justify permitting swimming in Canobie Lake.*

a. The Department cannot maintain that direct water transfers from Arlington Pond are 'safe', act on that belief, and then proceed to argue that swimming by shoreline residents is dangerous.

12. *Comparisons to Lake Sunapee are inappropriate because Sunapee stores significantly more water volume than Canobie, so swimmer impact per gallon is less.*

a. Untrue. The Department has used a misleading metric for comparison -- the total volume of a lake is immaterial. It is a widely understood scientific principal that deep water bodies *stratify* during the summer months and the surface layer does not mix with the bottom layer (*Exhibit 14*).

b. As swimming is a surface activity, the more appropriate comparison is # of swimmers per acre of surface area. By that comparison, recreational activity on Canobie will be significantly LESS than Sunapee:

LAKE	SIZE (acres)	Shoreline Households	Households Per Acre	# Public Beaches	# Public Boat Ramps
Sunapee	4085	900*	.22	2	2
Canobie	375	80	.21	0	0**

- *Estimate provided by Lake Sunapee Protective Association and does not include 'Funnel Developments' such as condominiums or housing developments that have shared access to the lake.
- ** The single boat ramp on Canobie Lake is permitted for use by Windham residents only.

13. *<u>Contrary to the Petitioners' assertion, the 'no-swim' rule has been enforced by the Canobie Lake Protective Association and others.</u>*

 a. See email from Dick Hannon, President of Canobie Lake Protective Association in which he acknowledges resident dockside swimming (*Exhibit 8*).
 b. See email from William Schroeder, a member of the Board of Directors for Canobie Lake Protective Association, encouraging the Apellant to withdraw the Waiver Application and swim quietly (*Exhibit 9*).

14. *<u>Granting the waiver application would set a precedent that would enable a great number of Canobie Lake Park guests to swim in the lake.</u>*

 a. The waiver application is seeking relief for <u>Residential Abutters</u> only, and the DES has the authority to place such a limitation. The park is zoned commercially. It is not clear how, or if, Canobie Lake Park could meet the hardship requirement for its own waiver application.
 b. Fear of precedent has never been an appropriate justification for limiting and individual's constitutional right to enjoy property in the U.S.
 c. The shoreline of the Park is walled by stone and inappropriate for use as a beach.

15. *<u>Treatment of the water by Salem does not justify removal of the no-swim rule as it is part of a multi-barrier protection system advocated by the USEPA.</u>*

 a. The Safe Water Drinking Act does not advocate for the specific elimination of swimming in reservoirs.
 b. Given the Department's approval of direct water transfer, there is no existing barrier to swimming.
 c. In 2002, the <u>Water Council</u> found that the presence of a treatment facility in Sunapee was adequate to ensure that the intent of RSA 485:24 and

485:25 is met-- a position that was subsequently upheld by the New Hampshire Supreme Court (*Exhibits 6&7*).

16. *The Towns of Salem, Windham, and the Canobie Lake Protective Association oppose the Waiver.*

   a. The Town of Salem petitioned the Department for the right to transfer water directly from Arlington Pond into Canobie Lake and expects to use this option as part of an ongoing water management policy:

      > "As stated, it is our [Town of Salem] intention to seek regulatory approval to initiate direct transfers on an "as needed" basis to maximize the use and storage capability of our two major supplies of raw water." (*Exhibit 4, page 5*).

   Salem cannot argue that water transfers are safe, and simultaneously argue that swimming by Canobie residents is dangerous.

   b. It is unclear why the officials of the Town of Windham oppose the waiver as they have no vested interest in the issue. Windham does not draw drinking water from the lake and has no municipal supply.
   c. The Canobie Lake Protective Association seeks to curb recreational use on the lake beyond swimming:

      > "It's not so much about swimming, as it is about what comes with it!" (email from President of the Association, *Exhibit 8*)

17. *The Simplex court case cited by the Appellants does not apply.*

   a. The Appellants anticipated resistance to the Waiver from the NHDES on every level, including technical merits. The Simplex case is cited only to demonstrate that the Appellants meet the hardship requirement as required under Env-Ws 386.04(d)(3). It is interesting, however, to note that the restriction would also be unsupportable a zoning context.

Exhibit 11

BY MIC H. STEWART
MARYLYNN V. YATES
MICHAEL A. ANDERSON
CHARLES P. GERBA
JOAN B. ROSE
RICARDO DE LEON
ROY L. WOLFE

The Metropolitan Water District of Southern California recently completed construction of an 800,000 acre-ft (1×10^9 m^3) drinking water reservoir. Recreational activities, including swimming and other sports involving direct body contact (BC) with the water, have been the subject of considerable interest by local community members. Consequently, a modeling-based risk assessment study was conducted to assess the potential public health consequences to downstream potable water users consuming water from this reservoir if BC recreation was permitted. Results of the study indicated that the annual risk of waterborne illness would increase three times above background, despite conventional treatment. Moreover, the occurrence of high-loading pathogen events associated with BC recreation was observed to significantly increase the daily risk of waterborne illness to downstream consumers. The study also considered the cost of additional treatment that would be necessary to address the increased risk. The modeling approach used in this study provides guidance for policymakers and stakeholders who are examining issues associated with BC recreation and drinking water reservoirs.

Predicted Public Health Consequences of Body-contact Recreation ON A POTABLE WATER RESERVOIR

Water-based recreational sports—such as swimming, waterskiing, use of personal watercraft (PWC), sailing, and fishing—may be considered an asset to those communities with lakes or reservoirs available for such activities. In many cases, these same bodies of water are also used as the primary source for drinking water. Consequently, the desire for recreational opportunities can be in conflict when these activities compromise the quality of drinking water sources. Moreover, emerging regulatory requirements that place greater emphasis on source water protection, coupled with community interest in meeting growing recreational demands or enhancing eco-

Body-contact recreational activities such as swimming and waterskiing on lakes and reservoirs used as drinking water sources can compromise the quality of the water.

nomic opportunities associated with water-based recreation, further complicate multiple-use practices at public reservoirs. Past studies have focused on the relationship between the quality of source water and the associated wastewater, industrial, and agricultural activities; however, few studies have addressed the effects of body-contact (BC) recreation (e.g., swimming, waterskiing, use of PWC, and other forms of recreation involving direct BC with the water) on drinking water quality. This study specifically addresses potential health consequences related to consuming water from a reservoir at which BC recreation is permitted.

The Metropolitan Water District of Southern California (MWDSC) recently completed construction of a drinking water reservoir with a surface area of 4,500 acres (1,800 ha) and a total storage capacity of 800,000 acre-ft (1×10^9 m^3). This reservoir (now named Diamond Valley Lake, but previously referred to as the Eastside Reservoir) will be able to deliver water to approximately 90% of MWDSC's 5,200 sq mi (13,000 km^2) service area, which serves more than 16 million people. Since 1992, MWDSC has worked with community-based groups to develop a comprehensive recreation plan for the reservoir complex, including an extensive assortment of recreational opportunities (camping, golfing, hiking, cycling, fishing, commercial villages, and so forth). During the course of this developmental process, some members of the local community proposed the inclusion of BC recreation at the main reservoir. Although MWDSC does not permit BC recreation at any of its other reservoirs and permitting this type of activity at the reservoir is inconsistent with existing state law, MWDSC agreed to investigate the public health implications of this activity for downstream consumers of potable water.

BC recreation is a known nonpoint source of fecal contamination in lakes and reservoirs that permit this activity (Levy et al, 1998; Kramer et al, 1996; Moore et al, 1994). There were reports of 36 outbreaks in lakes, creeks, or rivers that affected 2,135 recreationists from 1991 to 1996 (Kramer et al, 1996; Moore et al, 1994). Etiologic agents reported in these outbreaks included *Cryptosporidium parvum, Escherichia coli* 0157:H7, *Giardia lamblia, Shigella,* and *Naegleria fowleri.* The same stud-

TABLE 1 Studies documenting the input of pathogens and indicator organisms by people into recreational waters

Study	Organism(s) Studied	Recreational Uses Allowed
Carswell et al, 1969	Fecal indicator bacteria	All types
Stuart et al, 1971	Fecal indicator bacteria	Open versus closed reservoirs
Seierstad et al, 1993	Fecal indicator bacteria	All types versus no recreation
McMurran, 1997	Fecal indicator bacteria	Body-contact recreation versus no recreation at lake
Sherry, 1986	Fecal indicators, *Pseudomonas aeruginosa*	Study conducted at a bathing beach
Hanes & Fossa, 1970	Fecal indicators, *Staphylococcus, P. aeruginosa*	Swimming pool
Johnson et al, 1985	*Staphylococcus*	Swimming pool
Rose et al, 1987	Rotaviruses and enteroviruses	Full-contact bathing in a stream
Baron et al, 1982	Norwalk virus	Full-contact bathing at a lake
Bryan et al, 1974	Hepatitis A	Full-contact bathing at a lake
Keswick et al, 1981	Enteroviruses	Swimming pools
D'Angelo et al, 1979	Adenovirus type 4	Swimming pools
Sorvillo et al, 1990	*Cryptosporidium*	Swimming pools
Harter et al, 1984	*Giardia*	Swimming pool for infants and toddlers
Porter et al, 1988	*Giardia*	Swimming pools
Levy et al, 1998	*Cryptosporidium*	Water park

ies also reported 21 outbreaks affecting 9,679 recreationists in pools, water slides, and other artificial settings with similar etiologic agents. In at least seven of these pool-related outbreaks, the water was properly chlorinated and filtered. With the exception of cases involving *Shigella sonnei*, which are excreted only by humans, the source of pathogens for the outbreaks associated with the natural recreational settings may have been from animal sources. However, it is clear that outbreaks associated with swimming pools were caused by releases of pathogens by recreationists. More recently, outbreaks of cryptosporidiosis at recreational water parks have been reported in Clovis, Calif. (Cryptosporidium *Capsule,* 1997), and at a water park in Georgia (Levy et al, 1998). Table 1 summarizes studies documenting the input of pathogens (e.g., enteric viruses, *Giardia, Cryptosporidium, Staphylococcus, Pseudomonas aeruginosa*) and indicator organisms (e.g., coliforms) by people into recreational waters.

The health implications of consuming water (followin conventional treatment) from reservoirs permitting BC recreation have not been well documented. The lack o sufficient information to address this issue is a result, i part, of the limitations of current pathogen detectio methodologies, a lack of understanding of the hydrodynamics associated with pathogen movement in bodies o water, and a lack of appropriate epidemiological studies In an effort to predict the recreational effects on wate quality in Diamond Valley Lake and the associated healt risks to downstream consumers, a finite-segment model wa developed to estimate reservoir outlet concentrations of various pathogens, including *Cryptosporidium, Giardia* rotavirus, and poliovirus released by individuals engage in BC recreation. These pathogens were selected based o their documented potential for causing waterborne illnes and their persistent environmental survival characteristics. Results from the model simulations were then used a

TABLE 2 Input parameters used in Monte Carlo analysis*

Parameter	Distribution	*Cryptosporidium*	Rotavirus	*Giardia*	Poliovirus
Infection rate—*%*	Uniform	0–5	5–20	0–10	5–20
Feces shed—*g/person*	Log-uniform	0.01–1	0.01–1	0.01–1	0.01–1
Pathogen content of feces—g^{-1}	Log-uniform	10^5–10^7	10^7–10^9	10^5–10^7	10^6–10^8
AFR† frequency—*per 1,000*	Uniform	0–2	0–2	0–2	0–2
Mass of AFR—*g/AFR*	Uniform	50–150	50–150	50–150	50–150
Inactivation rate, epilimnion—d^{-1}	Uniform	0.016–0.15	0.1–0.5	1.1–1.65	0.28–0.88
Inactivation rate, hypolimnion—d^{-1}	Uniform	0.008–0.020	0.05–0.25	0.04–0.13	0.14–0.44

*From Yates et al, 1997
†AFR—accidental fecal release

input to dose–response models. This report provides results from the risk assessment and discusses treatment costs necessary to minimize waterborne illness associated with BC recreation in a drinking water reservoir.

METHODOLOGICAL APPROACH

A number of steps were used in the development of the pathogen risk assessment model. First, those pathogens that could enter the water as a result of BC recreation were identified based on a review of the scientific literature (Yates et al, 1997). The numbers of pathogens that would be input per recreationist were then calculated based on the incidence of infection in the population (Soave & Weikel, 1990; Ungar, 1990; Rodriguez et al, 1987; Champsaur et al, 1984; Sealy & Shuman, 1983) and the reported concentrations of these pathogens in fecal material (Robertson et al, 1995; Jakubowski, 1984; Flewett, 1982; Melnick & Rennick, 1980) (Table 2). It was assumed that pathogen input occurred in two ways:

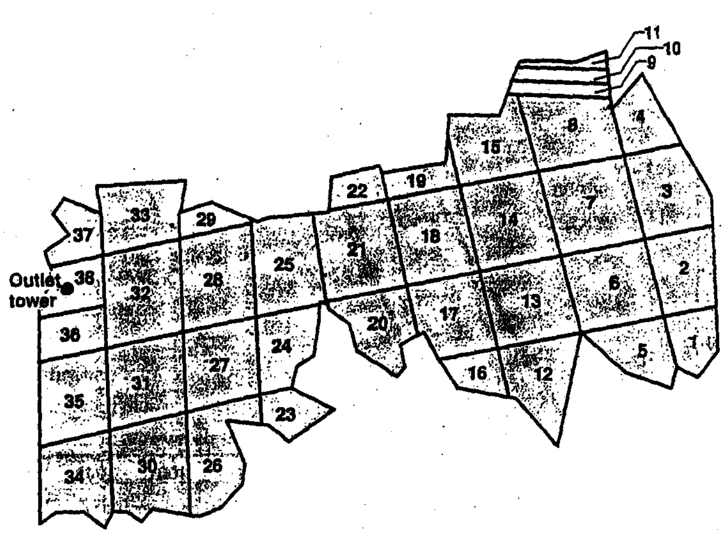
- from shedding of residual fecal material from recreationists' bodies upon contact with the water (assumed for all recreationists) and
- from accidental fecal releases (AFRs) (assumed for a small fraction of recreationists).

Next, the factors that would affect the pathogens once they had entered the reservoir (e.g., inactivation and sedimentation rates) were identified and quantified based on published studies of pathogen fate in surface water (Carrington & Ransome, 1994; Gerba et al, 1993; Robertson et al, 1992; Hurst et al, 1989; Raphael et al, 1985; Hurst & Gerba, 1980; Bingham et al, 1979).

A recreational plan, developed by a consulting firm in conjunction with the local community, identified a graduated series of recreational activities consisting of limited-BC (LBC) boating (defined as using small multihull sailboats, canoes, kayaks, and other related forms of boats that would involve BC with the water on a limited basis); LBC plus boating and waterskiing; LBC plus boating, waterskiing, and use of PWC (e.g., jet skis); and LBC plus boating, waterskiing, use of PWC, and swimming. Swimming was eventually dropped from consideration because of the unfavorable topography of the reservoir. All of these recreational activities were assumed to involve sufficient time (~10 min) in contact with the water to allow for pathogen release. Table 3 summarizes projected recreationist use rates for each of these activities. Two recreational scenarios were considered:

- full basin usage (FBU)—BC recreation throughout the reservoir—and
- east basin usage (EBU)—BC recreation restricted to the half of the reservoir that is farthest from the outlet tower.

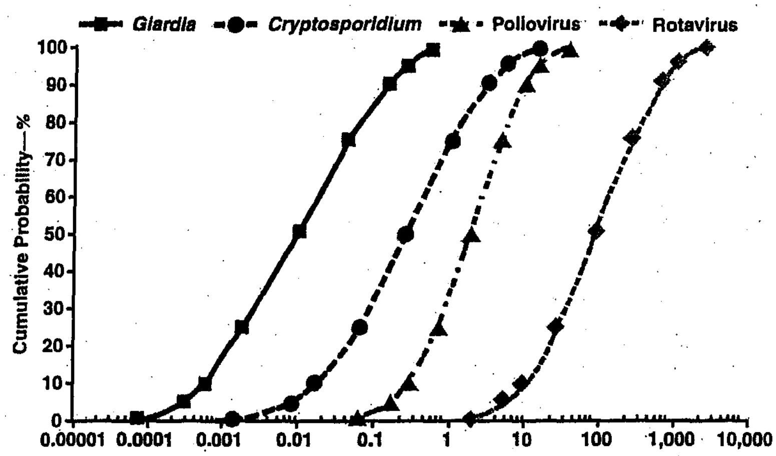
FIGURE 1 Grid for finite segment model of Diamond Valley Lake



Finite-segment model. Pathogen concentrations at the outlet tower of the reservoir were predicted by a finite-segment model (Thomann & Mueller, 1987) developed for Diamond Valley Lake. The reservoir was divided into 38 lateral segments, with each segment further divided into an upper epilimnetic zone of 6 m (20 ft) and a lower hypolimnetic zone (Anderson et al, 1998) (Figure 1). On the basis of data for other reservoirs in Southern California, stratification was assumed to commence in late April and persist into December. The model assumed that the reservoir volume varied from 500,000 to 700,000 acre-ft (6.2×10^7 to 8.6×10^7 m^3) during the year, with a mean annual volume of 600,000 acre-ft (7.4×10^7 m^3). It was further assumed that the reservoir was filled in the winter and drawn down in the summer, following a sinusoidal fill schedule. Segment volumes, depths, and cross-sectional areas were estimated from topographic maps and total reservoir volume. Exchange between the segments was modeled as a convective–dispersive process, whereas epilimnion–hypolimnion exchange was assumed to proceed through dispersion. Pathogen inputs were calculated based on projected recreationist use data (Table 3) and available information regarding rate of infection, fecal shedding rate, and pathogen content of feces (Yates et al, 1997). Pathogen loss from the water column was modeled assuming first-order inactivation, using available rate data. Loss of protozoan cysts from the water column by sedimentation was also included in the model.

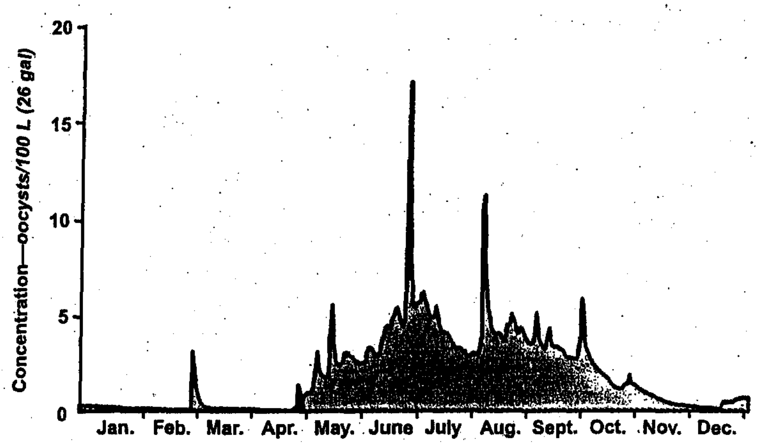
Sensitivity analysis demonstrated that the model was highly sensitive to parameters associated with pathogen loading and inactivation. Because of the variability in

FIGURE 2 Cumulative probabilities* of various concentrations of *Cryptosporidium, Giardia*, rotavirus, and poliovirus



***Includes probabilities for boating plus waterskiing and using personal watercraft under the full basin recreational scenario**

FIGURE 3 Model projection of *Cryptosporidium* concentration from body-contact recreation



parameter values reported in the literature, uncertainty analyses were conducted by means of Monte Carlo techniques in which 5,000 simulations were conducted for each recreational scenario using key input parameters that were randomly drawn from defined ranges (Table 2). The reader is referred to the work of Anderson and colleagues (1998) for additional details about the model.

Risk assessment. A risk assessment based on the calculated concentrations for the proposed BC recreational scenarios was performed to quantify the public health risks to consumers using water from Diamond Valley Lake. Two models were used to provide the best fit to the protozoa and virus data sets eva ated (Haas et al, 1996; Regli et 1991). The beta-Poisson model v shown to provide a good fit for rotavirus dose–response data, and exponential model was utilized poliovirus, *Cryptosporidium*, a *Giardia.*

The number of organisms to wh a consumer would be exposed w calculated for the various propos recreational scenarios by using t reservoir model described earlier. was assumed that all water leavi the reservoir would be treated at drinking water treatment plant. T extent of pathogen loss from the res voir outlet to the plant intake w predicted to be small (e.g., 0.4 7.2% for *Cryptosporidium*) becau of the short transit time. To be co sistent with the Surface Water Trea ment Rule (SWTR), the number pathogens in the water was assum to decrease by the following amoun during treatment:

- *Giardia*, 99.9% (3-log) re moval, and
- viruses, 99.99% (4-log) remova

Studies have been reported est mating that removal of *Cryptospo idium* may vary from 2 to 6 logs (Gar seff et al, 1998). The US Environment Protection Agency (USEPA) currentl assumes an average log removal of 2. (Regli et al, 1999). Because of the cri ical nature of this variable in the cu rent study, the *Cryptosporidiu* removal value was based on particl count studies conducted by MWDS (Cheng, 1996) at a filtration plant th would frequently receive water fro the reservoir. These studies demonstrated that on the basis of combined filter effluent parti cle counts, approximately 2.5 logs (99.68%) of particle of the same size as *Cryptosporidium* could be removed.

The risk to consumers was calculated for the variou recreational scenarios using the dose–response model Exposure to pathogens can lead to one of four differen endpoints: no effect, infection, clinical illness, or death There are quantitative risk models that characterize risl on the basis of specific population dynamics (Eisenberg e al, 1998; Eisenberg et al, 1996). However, the risks cal culated in this study were performed in a manner con sistent with that used by USEPA (Regli et al, 1991) t assist in evaluating the potential treatment costs of meet ing proposed regulatory standards and determining the treatment that is necessary to maintain the current microbial risk.

During the course of the reservoir model development and risk assessment calculations, it was observed that *Cryptosporidium* was the organism that had the greatest impact on risk to downstream potable water consumers. This is partially a result of the organism's ability to survive for extended periods in water environments, its resistance to inactivation by conventional disinfection practices, and the known adverse health consequences of contracting cryptosporidiosis. Moreover, an assumption was made that treatment practices effective for *Cryptosporidium* would, in general, be equally or more effective for other known pathogens. Consequently, the risk assessment results and corresponding costs for treatment presented in this report are based on this organism. Risk calculations were based on primary, not secondary, infections; thus, the reported values may underestimate the potential number of cases of cryptosporidiosis in the community receiving this water.

TABLE 3 Annual Diamond Valley Lake recreation forecasts

Type of Use	Non-BC* Recreationists	BC Recreationists	Totals
Full basin usage			
No BC	382,780	0	382,780
LBC† boating	377,780	50,100	427,880
LBC boating plus waterskiing	324,435	292,435	616,870
LBC boating plus waterskiing, and use of PWC‡	305,115	278,325	583,440
East basin usage			
No BC	382,780	0	382,780
LBC boating	377,780	50,100	427,880
LBC boating plus waterskiing	322,745	277,195	599,940
LBC boating plus waterskiing, and use of PWC	304,025	254,955	558,980

*BC—body contact
†LBC—limited body contact
‡PWC—personal watercraft

Relative risk. In addition to the risks calculated on the basis of predicted pathogen concentrations, the associated annual risk to consumers relative to a baseline level (hereafter referred to as relative risk) was calculated for both the FBU and EBU scenarios. Previous pathogen monitoring conducted at MWDSC established that the mean concentration of *Cryptosporidium* in the source waters used to fill the reservoir is 0.36 oocysts/100 L (26 gal). Because the reservoir is situated in a valley with steep sides and a very small watershed area (approximately 3,000 acres [1,200 ha])—and with no active agricultural operations, residences, or other point or nonpoint sources of pathogens—additional external inputs are minimal. Therefore, this concentration of 0.36 oocysts/100 L (26 gal) is the baseline against which the recreational impact was compared. Increasing the concentration to 1 oocyst/100 L (26 gal) in the reservoir (which, following a 2.5-log removal at the treatment plant, will meet USEPA's desired risk level of one infection annually per 10,000 people) increases the annual risk to the consumer by a factor of 2.78. Monte Carlo analysis was used to predict the probability that *Cryptosporidium* concentrations will not exceed some mean annual concentration.

Data interpretation. Data developed for the risk assessment calculations are presented at 95 and 99% confidence levels. At the 95% confidence level, 4,750 of the 5,000 simulations for a given recreational scenario yielded an annual average concentration below some value x, whereas 5% of the simulations yielded annual average concentrations greater than x. (That is, given the uncertainty in the input parameters, there is a 5% chance that the annual average concentration in the reservoir will exceed x. Analogously, at the 99% confidence level, there is only a 1% chance that the concentration will exceed its corresponding value.) The choice of the confidence level, as defined in this study, is important because it defines the probability that the concentration in the reservoir will exceed the concentration used in assessing the risk of infection by downstream consumers. In a similar manner, the choice of the confidence level also defines the probability of actual treatment costs exceeding those projected for a given level of treatment.

MODEL RESULTS

Predicted annual pathogen concentrations and associated annual risks to consumers. Results comparing annual average *Cryptosporidium*, *Giardia*, rotavirus, and poliovirus concentrations at the outlet tower can be expressed as cumulative probability distribution functions (CDFs). Figure 2 illustrates the CDF for boating plus waterskiing plus PWC under the FBU recreational scenario. For *Cryptosporidium*, the CDF shows that 95% of the simulations yielded annual average epilimnetic concentrations of 5.6 oocysts/100 L (26 gal). These probabilities are important, as they can be used to define the likelihood that pathogen levels will exceed a possible regulatory value. Predicted protozoan concentrations at the outlet tower were lower than viral concentrations at equivalent cumulative probabilities, with particularly high concentrations predicted for rotavirus. Median concentrations (i.e., concentrations corresponding to a 50%

TABLE 4 BC* recreation options and projected annual effects—95% confidence level

Recreationist Activity Options	Number of BC Recreationists	*Cryptosporidium* Concentration *oocysts/100 L (26 gal)*	Annual Risk of Infection *per 10,000 consumers*	Relative Risk
Full basin usage				
LBC† boating	50,100	1.1	1.1	3.2
LBC boating, waterskiing, and use of PWC‡	278,325	5.6	5.5	15.7
LBC boating and waterskiing	292,435	6.2	6.0	17.1
East basin usage				
LBC boating	50,100	0.7	0.64	1.8
LBC boating, waterskiing, and use of PWC	254,955	2.4	2.3	6.6
LBC boating and waterskiing	277,195	2.6	2.5	7.2

*BC—body contact
†LBC—limited body contact
‡PWC—personal watercraft

cumulative probability) increased from 0.01 cyst/100 L (26 gal) for *Giardia* to 0.27 oocyst/100 L (26 gal) for *Cryptosporidium* and 1.82 and 85.1 plaque-forming units (pfu)/100 L (26 gal) for poliovirus and rotavirus, respectively (Anderson et al, 1998).

Because of current concerns about *Cryptosporidium*, including treatment considerations, subsequent results evaluating the proposed recreational scenarios focused on *Cryptosporidium*. Figure 3 illustrates the predicted concentration of *Cryptosporidium* oocysts at the outlet tower from an arbitrary simulation over the course of a year. As expected, the concentrations are higher during the season that corresponds with the highest recreation activity. There are, however, periods when the concentration rises sharply above the background and then returns to baseline levels, suggesting that pathogen concentrations are not uniform in nature. Annual concentrations represent the average concentrations of pathogens (including peaks) over a year's period. The significance of the peak events is addressed here.

Table 4 summarizes the predicted public health effects of the proposed BC recreational plans at a 95% confidence level. In general, the model predicted that the mean annual *Cryptosporidium* concentrations would increase linearly with increasing recreationist use. The annual risk of infection associated with the predicted annual average concentration ranged from up to 1.1 to 6 per 10,000 consumers, with a relative risk ranging from 3.2 to 17.1 times background. Based on an [estimated] service area containing 3.5 [mil]lion people, the model predicts a [5%] probability that the annual numb[er of] additional infections caused by [BC] recreationists could exceed the r[ange] of 385–2,100 infections under the [FBU] scenario (Figure 4). Without BC re[cre]ation, the model predicts a theo[reti]cal number of infections in the c[om]munity of 126 individuals per ye[ar].

If recreation was restricted to I[LBC] only—and assuming that a 95% c[on]fidence level is acceptable—the p[ro]posed scenario of 50,100 LBC re[cre]ationists would be permissible with[out] the need for additional treatmen[t to] reduce concentrations to levels acc[ept]able to USEPA, although the rela[tive] risk to consumers would be up to [1.8] times higher than current levels (Ta[ble] 4). The annual risk of infection [cal]culated from the 95% levels for *Cryptosporidium* c[on]centrations ranged from 0.64 to 2.5 per 10,000 c[on]sumers, which is equivalent to 224–875 individual[s in] the service area (Figure 5). The relative risk was calcula[ted] to range from as much as 1.8 to 7.2.

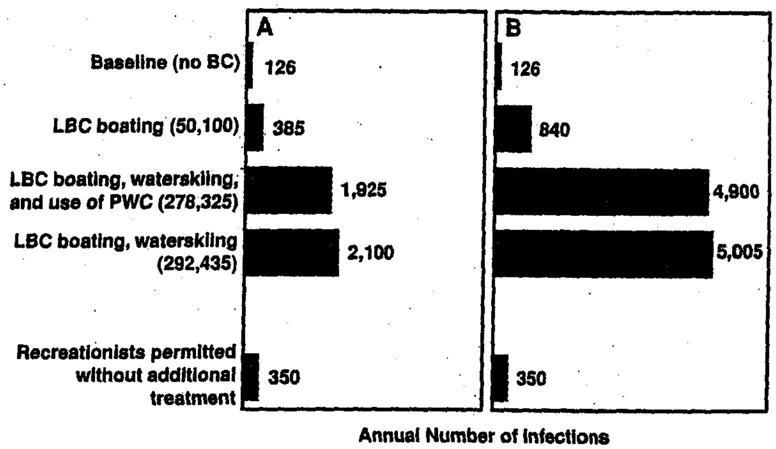
At the 99% confidence level (Table 5), at which o[nly] a 1% probability exists of underestimating the ann[ual] average *Cryptosporidium* concentration, all propo[sed] recreational scenarios would require additional tre[at]ment. For FBU, the annual risk of infection ranged fr[om] up to 2.4 to 14.3 per 10,000 consumers, and the re[la]tive risk ranged from up to 6.9 to 41 times backgrou[nd]. The model predicts a 1% probability that the number [of] individuals infected per year as a result of BC recreati[on] would exceed the range of 840–5,005 in the service a[rea] (Figure 4). Under EBU, annual risk ranged from up [to] 1.2 to 6.7 per 10,000 consumers, and relative risk rang[ed] from up to 3.5 to 19.1 times background, with up [to] 420–2,345 individuals infected per year in the commun[ity] (Figure 5). Maximum annual average concentrations [of] approximately 200 oocysts/100 L (26 gal) (or a relati[ve] risk of 660) and 100 oocysts/100 L (26 gal) were fou[nd] for the FBU and EBU scenarios, respectively.

In addition to assessing the proposed recreational pla[ns,] the model was used to predict the maximum number [of] BC recreationists that could be permitted under eith[er] the FBU or the EBU scenario without the need for add[i]tional treatment. At a 95% confidence level under FB[U]

These results suggest that placement of recreational activities at a distance from water intake structures can be used to attenuate the level of pathogens entering a treatment pla

32,000 BC recreationists could be accommodated on an annual basis without additional treatment. At a 99% confidence level, only 12,500 BC recreationists could use the reservoir without the need for additional treatment. EBU resulted in *Cryptosporidium* concentrations and associated annual risk levels that were lower than those for FBU with equivalent recreationist numbers and confidence levels. Restricting use to the east basin reduces pathogen loading near the outlet tower because of the increased losses from inactivation and sedimentation during transport from the east basin to the outlet tower. At the 95% confidence level, it is estimated that approximately 81,000 recreationists could be accommodated without additional treatment, whereas that number of recreationists drops to 27,000 per year for the 99% level. It is essential to note that under all conditions in which BC recreationists are allowed, the risk of *Cryptosporidium* infection to downstream consumers increases approximately threefold relative to current levels.

FIGURE 4 Proposed BC recreation and projected annual infections under full basin usage scenario—95% (A) and 99% (B) confidence levels



BC—body contact, LBC—limited BC, PWC—personal watercraft

Predicted peak *Cryptosporidium* concentrations and associated daily risks to consumers. In addition to the annual average concentrations, predicted peak daily concentrations at the outlet tower were determined for each of the 5,000 simulations conducted for each scenario. Although it is unlikely that regulatory requirements would be based on peak concentrations, these events are extremely important because they define the maximum concentrations that might be entering the water treatment plant, which could result in sporadic episodes of waterborne illnesses. For FBU, the associated relative risk factors were generally 3.5–4 times higher than the corresponding annual average concentrations. At the 95% confidence level (i.e., at a 5% probability of underestimating the peak *Cryptosporidium* concentration) and depending on the number of BC recreationists, the peak concentrations of *Cryptosporidium* ranged from approximately 5 oocysts/100 L (26 gal) to more than 20 oocysts/100 L (26 gal), with a corresponding relative risk that ranged from approximately 13 to 60 times higher than background (Table 6). At the 99% confidence level, these values ranged from approximately 12 to 50 oocysts/100 L (26 gal), with a corresponding relative risk that ranged from approximately 30 to 140 times higher than background (Table 7). Maximum peak values were predicted to be approximately 2,500 oocysts/100 L (26 gal), with a relative risk of 6,600 for the downstream consumer. The estimated number of daily infections ranged from 12 to 49 for the proposed BC recreational scenarios, with a maximum daily infection level of 2,325 individuals in the community (Figure 6).

For the EBU scenario, peak concentrations were about 2–2.5 times higher than the corresponding annual average values, ranging from about 1 to 16 oocysts/100 L (26 gal), depending on confidence level (Tables 6 and 7). Maximum peak values were predicted to be approximately 1,300 oocysts/100 L (26 gal), with a corresponding relative risk 3,600 times higher than background. As with the annual average case, peak concentrations were lower for EBU than for FBU. Estimated daily infections ranged from < 2 to 15, depending on the level of BC recreation (Figure 7). The maximum daily infection level was estimated at 1,200 individuals.

DISCUSSION

The public health issues associated with water-based BC recreation are frequently discussed in terms of illnesses contracted by the recreationists. (Note: Infection was used as the endpoint for the current study to be consistent with the methods used for drinking water regulations; infection can be converted to illness by using a pathogen-specific ratio of cases of illness to cases of infection.) Epidemiological studies were conducted as early as 1953 to assess the risk of illness associated with swimming in bodies of water (Stevenson, 1953). Since that time, reports of illnesses associated with BC recreation have confirmed that recreationists can release pathogens into bodies of water and are at risk of illness from these activities or from contaminants already present in the water. In an effort to address these concerns, USEPA has published a document to provide guidance to agencies governing recreational waters (Armitage et al, 1999). In contrast, there are no US regulatory statutes or guidance for BC recreation on drinking water reservoirs. In general, this issue is typically addressed by state or local regulatory agencies. The existing health code in California does not permit BC

TABLE 5 BC* recreation options and projected annual effects—99% confidence level

Recreationist Activity Options	Number of BC Recreationists	*Cryptosporidium* Concentration *oocysts/100 L (26 gal)*	Annual Risk of Infection *per 10,000 consumers*	Relative Risk
Full basin usage				
LBC† boating	50,100	2.48	2.4	6.9
LBC boating, waterskiing, and use of PWC‡	278,325	14.5	14.0	40.2
LBC boating and waterskiing	292,435	14.8	14.3	41
East basin usage				
LBC boating	50,100	1.26	1.2	3.5
LBC boating, waterskiing, and use of PWC	254,955	6.67	6.5	18.5
LBC boating and waterskiing	277,195	6.87	6.7	19.1

BC—body contact
†LBC—limited body contact
‡PWC—personal watercraft

TABLE 6 BC* recreation options and projected daily effects—95% confidence level

Recreationist Activity Options	Number of BC Recreationists	*Cryptosporidium* Concentration *oocysts/100 L (26 gal)*	Daily Risk of Infection *per 1 million consumers*	Relative Risk
Full basin usage				
LBC† boating	50,100	4.8	1.3	13.2
LBC boating, waterskiing, and use of PWC‡	278,325	21.8	5.8	60
LBC boating and waterskiing	292,435	21.4	5.7	59
East basin usage				
LBC boating	50,100	1.2	0.3	3.4
LBC boating, waterskiing, and use of PWC	254,955	5.7	1.5	15.7
LBC boating and waterskiing	277,195	6.1	1.6	16.8

BC—body contact
†LBC—limited body contact
‡PWC—personal watercraft

recreation on reservoirs used for drinking water; however, a number of exemptions exist that provide for a range of various recreational activities in drinking water reservoirs throughout California. In a 1994 survey of recreational use of 55 California municipal drinking water reservoirs, it was observed that swimming, jet skiing, waterskiing, and LBC boating (e.g., windsurfing, small multihull sailboating, and kayaking) were allowed in 9, 13, 16, and 38%, respectively, of the reservoirs surveyed (DA, 1996). Some reservoirs allowed a mixture of various BC recreational activities. Of the 55 reservoirs surveyed, 33 (60%) exclude all recreation or allow only non-BC boating (e.g., fishing). The authors were interested to find that 50 (91%) of these reservoirs did not allow swimming. It is likely that a similar dichotomy of uses exists in other states as well. The consistent usage policy regarding recreation probably results fror number of factors, including—l not limited to—the following:

- inadequate data on the wa quality changes associated with recreation,
- conflicting recreational polic
- lack of regulatory statutes,
- assumptions concerning a quacy of existing treatment, and
- community interest in recreati

The current study was undertak to provide a scientific assessment the potential microbial risks to dov stream potable water users from l recreation.

The model determined that t addition of BC recreation to D mond Valley Lake would increa the number of pathogens releas into the reservoir, thus increasing t loading of pathogens entering t treatment plant. The primary co cern to downstream consumers w determined to be increased risk infection by *Cryptosporidium*. D pending on the confidence level ar number of BC recreationists, tl annual risk of infection under FB conditions ranged from 3 to 41 tim above background. The correspon ing number of infections in the cor munity would range from up to 3 to 5,005 annually. In contrast, wh the BC recreationists were restrict to the portion of the reservoir fa thest from the outlet tower, the a nual risk of infection ranged fro 1.8 to 19 times background, with corresponding community infection level of up to 224 2,345. These results suggest that placement of recreation activities at a distance from water intake structures can used to attenuate the level of pathogens entering a trea ment plant.

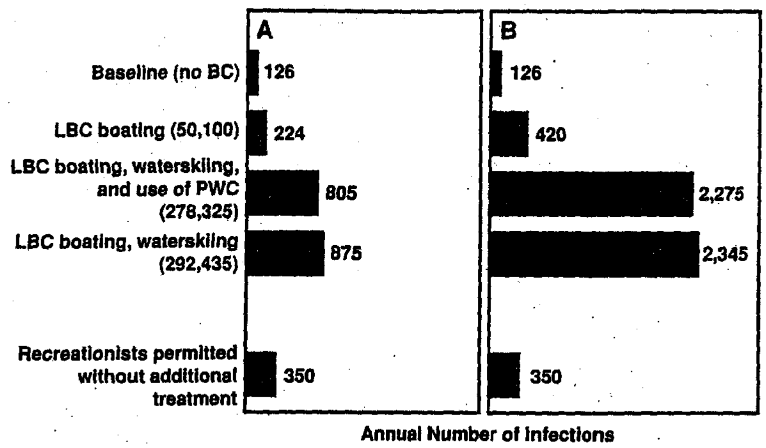
The model was also used to predict transient episod of elevated pathogen levels that might occur. Dependi on the confidence level and number of BC recreationis under FBU conditions the relative risk ranged from up 13.2 to 6,600 times higher than background. The nur ber of daily infections associated with these peak ever was estimated to be as high as 2,325. When BC recreatic was restricted to the east basin, the impact of peak ever was less significant—with a predicted maximum dai infection of 1,200 individuals in the community—than would have been with BC recreation allowed over the entire reservoir. Although it is unlikely that regulatory requirements would be based on peak pathogen concentrations, it is these episodes that can most often result in sporadic, and frequently undetected, increases in waterborne illness. Pathogen loading events well above background levels have been reported in the literature (Ferguson et al, 1998; LeChevallier et al, 1998) and have been suggested by some investigators as contributing to or being directly responsible for reported outbreaks (Atherton et al, 1995; Lisle & Rose, 1995).

During the course of this study, it was recognized that the model had a number of limitations. For example, the model had previously been shown to be highly sensitive to parameters defining pathogen inputs (Anderson et al, 1998). In many cases, only limited data were available to define the parameter distributions used in the Monte Carlo analyses. Thus, deviations from the assumed distributions (e.g., uniform, lognormal) would have a potentially significant effect on predicted concentrations and risk levels. Moreover, the results presented in this study reflect the risk associated with exposure to a single type of organism during water consumption. A variety of microorganisms will be present in the water at any given time; consequently, the total risk of waterborne microbial infection is, in part, a function of the sum of the risk from each type of organism. The risk assessment in the current study considered only four pathogens—*Cryptosporidium*, *Giardia*, rotavirus, poliovirus—among hundreds that could be present in fecal material and thus in the water. These four pathogens were considered to have the most potential importance for purposes of the study, but other pathogens may pose similar or greater health risks to consumers; however, limited scientific information precludes an accurate assessment of these organisms at this time. Consequently, the risk levels presented in this study should be considered the minimum aggregate risk to which the consumer will be exposed. It was also recognized that information regarding transport and survival of pathogens in bodies of water is scarce. In many cases, values from the literature were extrapolated for purposes of the model. One issue requiring additional study concerns the fate of dispersed versus intact fecal material. While AFRs accounted for only half of the total pathogen loading, the occurrence of large masses of fecal material containing pathogens greatly affected peak loading events. It is these events that will probably present the greatest treatment challenge.

Scientific studies designed to document quantitative release of microorganisms from individuals are limited, but they do provide support for the current model. Hanes and Fossa (1970) documented levels of coliforms shed by swimmers after 15 min in a swimming pool. Similar studies were later reported by Rose et al (1991) and by Smith and DuFour (1993). Studies have also been conducted under natural settings: Rose and colleagues (1987) examined the water quality of Oak Creek, a recreational stream in Arizona, for rotaviruses and enteroviruses above and below an area heavily used by bathers. No viruses were detected upstream of the recreation area; however, significant concentrations of viruses were found downstream. This study (Rose et al, 1987) determined that the average contributions of viruses per individual in contact with the water were 0.67 rotaviruses/100 L (26 gal) and 0.045 enteroviruses/100 L (26 gal). Using the approach developed for the current model, the levels of viruses released were estimated at 0.057 rotaviruses/100 L (26 gal) and 0.000341 polioviruses/100 L (26 gal). Even accounting for a recovery efficiency of 50%, these figures are 23 and 264 times lower than those reported by Rose and colleagues (1987), suggesting that the model is somewhat conservative. Finally, the model predicted that the occurrence of extremely high peaks would occur < 1% of the time. Field monitoring of MWDSC's source waters indicated that a nonuniform distribution of pathogen levels with peak pathogen levels (e.g., above the 90th percentile) was observed in only 0.8% of all monthly samples collected since 1994.

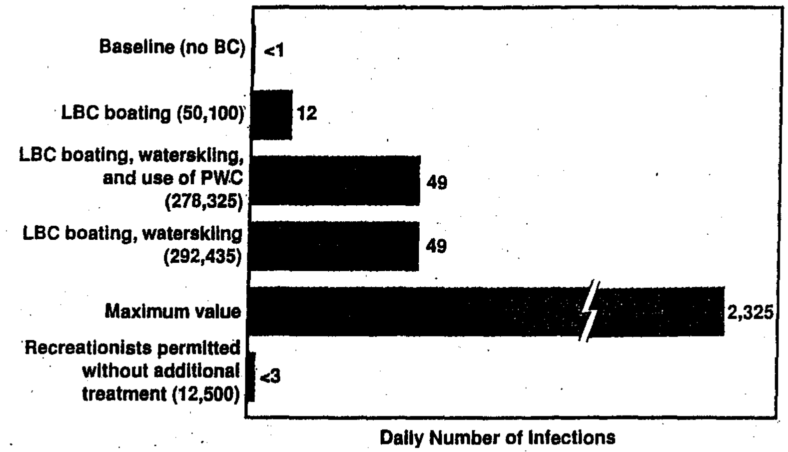
Several strategies for limiting increased pathogen concentrations resulting from BC recreation were considered as part of the study. The model predicted that pathogen levels could be attenuated to some extent by restricting BC recreational activities to the portion of the reservoir farthest from the outlet tower. Even under these circumstances, however, the annual risk was above background, and depending on the recreationist numbers, the annual

FIGURE 5 Proposed BC recreation and projected annual infections under east basin usage scenario—95% (A) and 99% (B) confidence levels



BC—body contact, LBC—limited BC, PWC—personal watercraft

FIGURE 6 Proposed BC recreation and projected daily infections under full basin usage scenario—99% confidence level



BC—body contact, LBC—limited BC, PWC—personal watercraft

TABLE 7 BC* recreation options and projected daily effects—99% confidence level

Recreationist Activity Options	Number of BC Recreationists	*Cryptosporidium* Concentration *oocysts/100 L (26 gal)*	Daily Risk of Infection *per 1 million consumers*	Relative Risk
Full basin usage				
LBC† boating	50,100	12.3	3.3	34
LBC boating, waterskiing, and use of PWC‡	278,325	52.7	14.0	146
LBC boating and waterskiing	292,435	50.8	13.5	141
Maximum value	NA§	2,500	664	6,600
East basin usage				
LBC boating	50,100	2.1	0.55	5.7
LBC boating, waterskiing, and use of PWC	254,955	15.8	4.2	44
LBC boating and waterskiing	277,195	15.2	4.0	42
Maximum value	NA	1,300	342	3,600

*BC—body contact
†LBC—limited body contact
‡PWC—personal watercraft
§NA—not applicable

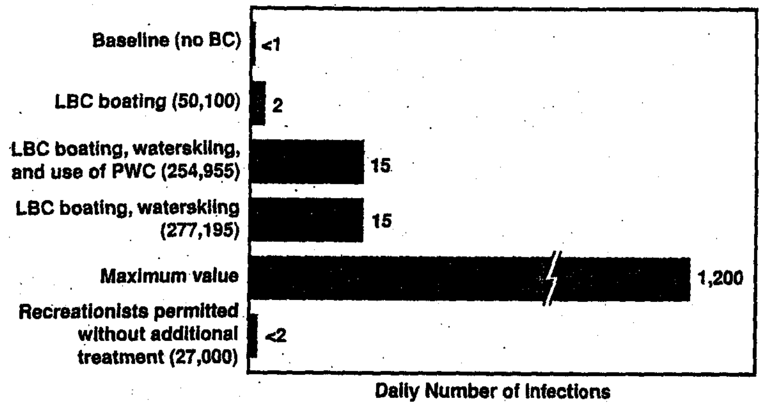
risk could still rise to 19 times higher than background. Moreover, peak events were noted to increase the daily risk of infection to as high as 44 times above background. Because the reservoir outlet tower will be designed with several tiers to enhance selective withdrawal of water from various levels, the model was used to predict pathogen concentrations occurring in the epilimnion and hypolimnion. In general, it was observed that predicted annual average pathogen concentrations near the outlet tower in the hypolimnion were 10–1,000 times lower than those observed for the epilimnion (Anderson et al, 1998). However, during the course of the year, especially when algae blooms are producin undesirable taste and odor con pounds, it may be necessary to r move water from the epilimnion. Th operational mode has been use extensively at MWDSC to provic acceptable water quality to con sumers. Consequently, selective witl drawal of water to achieve potenti pathogen reduction may result in selection of water that would not b aesthetically acceptable to the con sumer. Moreover, one of the highe spikes of *Cryptosporidium* observe during the past five years of mon toring of MWDSC's source wate reservoirs occurred in the hypo limnion. There was no apparen explanation (e.g., runoff events o changes in land practices) to accoun for this spike. Clearly, until additiona studies are performed to delineat pathogen movement in bodies o water, the use of selective water with drawal cannot be used as a reliabl method to control pathogen concen trations entering drinking water treat ment plants.

Treatment alternatives. Various treatment alternatives were also investigated to determine the most cost-effective means of achieving additional pathogen (especially *Cryptosporidium*) reduction at MWDSC's existing treatment facilities. Treatment was calculated to meet potential regulations (i.e., reduction of pathogens to meet a risk factor of 1 in 10,000) and to maintain current baseline levels. It was determined that the most cost-effective treatment alternative was to provide ozone disinfection in addition to the existing treatment process. If BC recreation was allowed, but at recreationist numbers that resulted in source water *Cryptosporidium* concentrations below 1 oocyst/100 L (26 gal), no additional treatment would be necessary to meet proposed regulations (the risk relative to baseline would increase 2.8 times). In order to maintain the consumer risk at current levels, however, additional ozone treatment would be required. A reduction from 1 oocyst/100 L (26 gal) to current baseline *Cryptosporidium* levels of 0.36 oocysts/100 L (26 gal) would require approximately a 0.5-log inactivation at a capital cost of $152 million and an annual operations and maintenance (O&M) cost of $3.8 million. BC recreational scenarios resulting in source water *Crypto-*

sporidium concentrations exceeding 1 oocyst/100 L (26 gal) would require additional treatment to meet the risk factor of 1 in 10,000. Capital and annual O&M costs associated with ozone treatment under these conditions would range from $170 million to $190 million and from $4.5 million to $5.2 million, respectively. However, increasing the ozone dosage to achieve greater log inactivation of oocysts may result in violation of the bromate regulations.

Bench-scale experiments with ultraviolet (UV) radiation indicate that *C. parvum* is relatively sensitive to this disinfectant. Results from medium-pressure and pulsed UV lamps have indicated that doses as low as 7.5 and 11 mJ/cm^2 inactivate, respectively, 1 and 2 $\log_{10}$ infectious oocysts (Mofidi et al, 2001). Large-scale application of UV radiation, although promising, may be time- and cost-prohibitive at present.

FIGURE 7 Proposed BC recreation and projected daily infections under east basin usage scenario—99% confidence level



BC—body contact, LBC—limited BC, PWC—personal watercraft

Although the final treatment requirements have not been resolved in the Enhanced SWTR, if the construct of the 1:10,000 risk level currently favored by USEPA is maintained, then additional treatment—presumably based on source water pathogen levels—may be required.

Economic analysis. In addition to evaluating the potential health aspects related to consumption of water subject to BC recreation, studies were performed to estimate the economic benefits of adding BC recreation to the reservoir (Husing, 1998; FAI, 1995). These studies indicated that annual direct spending by BC boaters visiting the reservoir would add from $3.6 million to $8.7 million to reservoir spending and from $7.6 million to $13.9 million to regional economic activity. This would enhance the revenue of the surrounding community, the annual retail sales of which are estimated at approximately $417 million. These economic studies, however, did not report any uncertainty associated with the projections; consequently, it is not known whether the addition of BC recreation would result in a statistically discernible increase of revenues for the area. Nevertheless, there was a perception that this activity would be economically beneficial, thus necessitating the treatment cost evaluations described earlier.

The studies did not address economics associated with waterborne illness. The annual cost of illness for downstream potable water users, based on values reported by Regli et al (1999), would range from $273,000 to $6.1 million, depending on the confidence level, usage scenario, and number of BC recreationists. These estimates do not consider the value of avoiding pain and suffering, the economic premium associated with risk aversion, the costs of averting behaviors, or even the cost of mortality. Moreover, these values are based only on *contracting* cryptosporidiosis and did not estimate secondary spread. Consequently, the actual cost associated with waterborne illness could be much higher. Moreover, the current value of death prevented is considerable and has been estimated at $5.6 million ± 3.16 million, with a cap of $16.87 million per death (Regli et al, 1999). These values would indicate that the economic loss associated with waterborne illness may well be equivalent to or greater than the estimated revenues related to the addition of BC recreational activities.

CONCLUSIONS

In conclusion, the results of this study indicate that BC recreation

- will increase the concentration of pathogens, including *Cryptosporidium,* in the reservoir;
- will increase waterborne illnesses for downstream consumers;
- may result in increased treatment costs for treatment plants receiving water from Diamond Valley Lake; and
- may result in an economic loss that is equivalent to or greater than the proposed revenues associated with the addition of BC recreational activities.

Clearly, a number of issues need to be addressed when activities that affect bodies of water that are used as drinking water sources are considered. In the current study, the desire to include BC recreation at a drinking water reservoir was evaluated to assess public health consequences and potential social and economic benefits to the community. The results of this study will be useful for utilities that currently permit or are considering permitting BC recreation in source water reservoirs. These results will be especially important in the consideration of future regulations that base treatment requirements on pathogen levels in source waters. The use of models such as those presented in this study are extremely valuable in light of the limited information available on pathogen levels associated with BC recreation. Ultimately, improvements in monitoring and detection methodology for pathogenic organisms will be needed to further refine the model. Information derived from these models is critical in developing appropriate treatment and reservoir management strategies to minimize the risk of microbial illness. In addition, scientifically based information such as this can provide guidance to policymakers and stakeholders who are examining the issues associated with BC recreation.

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Exhibit 12

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MODELING THE IMPACT OF BODY-CONTACT RECREATION ON PATHOGEN CONCENTRATIONS IN A SOURCE DRINKING WATER RESERVOIR

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(First received May 1997; accepted February 1998)

Abstract—A modeling study was conducted to evaluate the impact of body-contact recreation (e.g., water skiing, jet skiing, swimming) on pathogen concentrations in a source drinking water reservoir under construction in eastern Riverside County in Southern California. A hybridized Monte Carlo-finite segment model was used to predict pathogen concentrations in the reservoir resulting from pathogen inputs associated with shed fecal material and accidental fecal releases (AFRs). Monte Carlo techniques were incorporated into the finite segment model to define characteristics about individual recreators which affect pathogen loading to the reservoir (e.g., infection, pathogen shedding rate, location). Results of simulations are provided in the form of cumulative distribution and probability density functions derived from uncertainty analyses. The model predicted considerable spatial and temporal variability in pathogen concentrations within the reservoir, with elevated levels of *Cryptosporidium*, rotavirus, and poliovirus in the epilimnion during periods of high recreational use. Predicted *Giardia* concentrations were lower than the other pathogens. Hypolimnetic concentrations of all pathogens were generally 1–3 orders of magnitude lower than the overlying epilimnetic concentrations. Model results also suggest that field sampling will underestimate the mean, range and variance of pathogen concentrations in the reservoir. The model was further modified to include a particle tracking scheme to allow for transport of aggregated fecal material. Results from simulations using this approach demonstrate a potential for high pathogen loads due to body-contact recreation periodically reaching treatment plants. © 1998 Elsevier Science Ltd. All rights reserved

Key words—recreation, water quality, *Cryptosporidium*, *Giardia*, rotavirus, poliovirus, modelling

INTRODUCTION

Considerable interest exists for multiple use of public reservoirs in California and throughout the United States. Use which includes *body-contact* recreation, such as swimming, water skiing, and personal water craft (PWC) use, has potential ramifications, however, for reservoirs whose primary objective is the storage and supply of drinking water. Enteric pathogens, including bacteria, viruses and protozoa, may be shed into water during recreation from residual fecal material (Rose *et al.*, 1991a,b) and from so-called accidental fecal releases (AFRs) (Moore *et al.*, 1994). Inputs resulting from human contact will increase pathogen concentrations in the reservoir, and thus may increase health risks to downstream consumers receiving this water. Such inputs may also increase treatment costs. The magnitude of the impacts of recreation on water quality remains poorly understood, however.

Swimming and other recreational activities in which water is ingested are known to increase the risk of gastrointestinal illness to recreators (Kramer *et al.*, 1996). Fifteen outbreaks of waterborne disease affecting 1470 recreators in natural water bodies were documented in the US between 1991 and 1994 (Moore *et al.*, 1994; Kramer *et al.*, 1996). Etiological agents included *Cryptosporidium*, *Giardia*, *Escherichia coli*, and *Shigella*. Recreational activities have also been shown to increase the risk of gastrointestinal illness in non-outbreak settings (Calderon *et al.*, 1991; Kramer *et al.*, 1996). Such non-outbreak conditions, while potentially significantly increasing background levels of illness, are largely undetected and unreported by health organizations.

Construction is presently underway for an 800,000 acre-foot capacity raw drinking water storage reservoir in eastern Riverside County, CA (Fig. 1). When completed and filled in approximately 2002, the reservoir will effectively double the drinking water storage capacity in Southern California. The reservoir will also substantially

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increase the potentially available surface acreage for water recreational sports such as boating, water skiing, and PWC use. Because of the limited information about the impacts of body-contact recreation on water quality, a modeling study was conducted to predict *Cryptosporidium*, *Giardia*, poliovirus and rotavirus concentrations in the reservoir. Modeling plays a unique role in this water quality assessment because the reservoir is presently only under construction.

Models are routinely used in water quality studies and decision making (Orlab, 1992). The basis for many surface water quality models is the finite-segment approach, which provides a simple finite difference approximation to convection–dispersion-reaction equations (Thomann and Mueller, 1987). For example, Thomann *et al.* (1991) used finite segment models to describe polychlorinated biphenyl accumulation and fate in the Hudson River estuary and to predict the impact of bioturbation on the fate of cadmium at a Superfund site (Thomann *et al.*, 1993). In most models, inputs of contaminants are generally either treated as a spatially (and temporally) well-defined point discharge or as a distributed source. For this study, the contaminant sources are recreators, and as such, inputs are neither spatially nor temporally well-defined. Furthermore, the magnitude of contaminant inputs (pathogens in this study) can be expected to vary quite substantially across the recreator population.

APPROACH

Impacts of recreational activity on water quality were assessed using a hybridized Monte Carlo-finite segment model approach. A finite segment model following Thomann and Mueller (1987) formed the basis for the numerical model. Monte Carlo (MC) techniques were incorporated into the finite segment model to define characteristics about individual recreators (e.g., infection, pathogen shedding rate) which affect overall pathogen loading to the reservoir. Due to uncertainty in a number of important model parameters, results are based on uncertainty analyses (Reckhow, 1994) in which multiple simulations were conducted using values for population or global model parameters randomly drawn from within ranges reported in the literature.

Finite segment model

The reservoir was divided into 38 lateral segments (Fig. 1), with each segment further divided into an upper (6 m) epilimnetic zone and a lower hypolimnetic zone. The depth of this lower zone, which was considered to include both the metalimnion and hypolimnion during summer stratification, was a function of the local topography and total volume

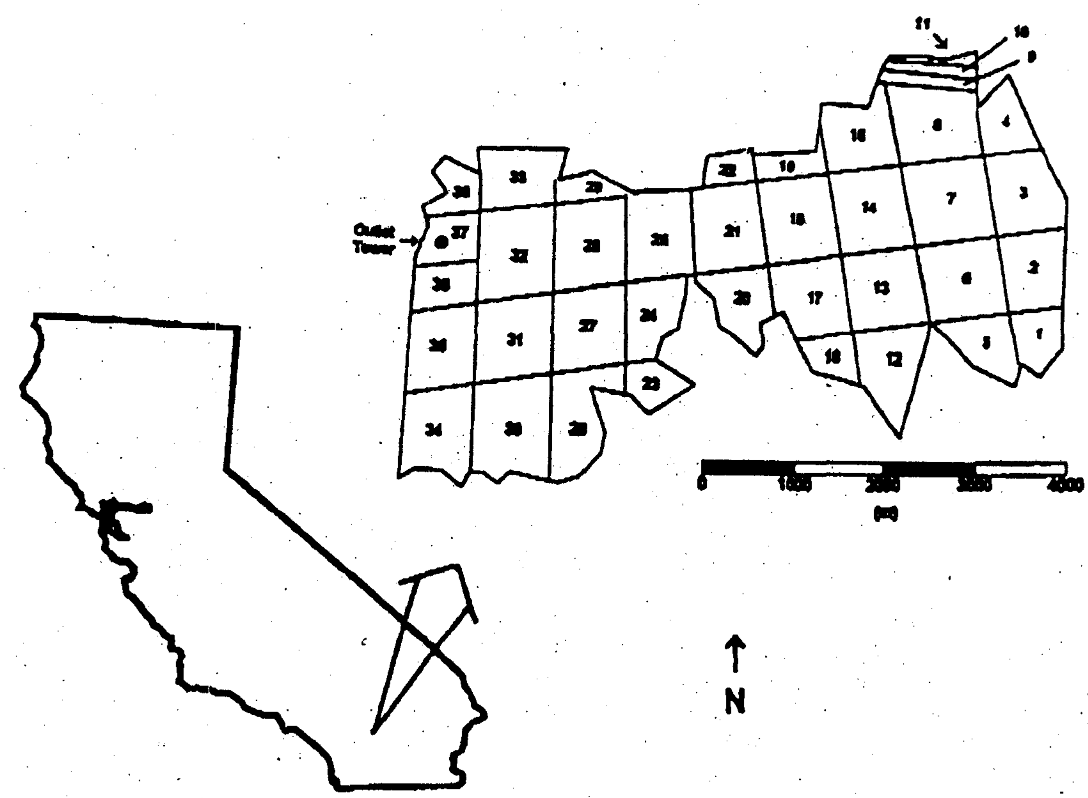

Fig. 1. Study site and segmentation grid used in finite segment model: the proposed Eastside Reservoir, near Hemet, CA.

of the reservoir, and varied from about 5 to 65 m depending on segment location. Segment 37 bounds the inlet/outlet tower, while segment 11 bounds a proposed beach site near the northeast end of the reservoir. The model assumed the total reservoir volume varied from 500,000–700,000 acre-feet during the year, with a mean annual volume of 600,000 acre-feet (MWD, unpublished data). It was further assumed the reservoir was filled in the winter and was drawn down in the summer following a sinusoidal fill schedule. Segment volumes, depths, and cross-sectional areas were estimated from topographic maps and total reservoir volume. Exchange between the lateral segments was modeled assuming convective–dispersive transport while epilimnion–hypolimnion exchange was modeled assuming dispersive transport. The dispersion coefficient for epilimnion–hypolimnion exchange was varied from approximately $0.1\ m^2/d$ during summer stratification to $500\ m^2/d$ during the winter. Stratification was assumed to commence in late April and persist into December based on data for other reservoirs in Southern California (Lund *et al.*, 1994). Pathogen inputs were calculated based upon projected recreator use data and available information regarding rate of infection, fecal shedding rate, and pathogen content of feces. Pathogen loss from the water column was modeled assuming first-order inactivation, using available rate data. Losses of protozoan cysts from the water column by sedimentation was also included in the model.

The change in number of pathogens in any segment i (N_i) under conditions of varying volume as a function of time (t) is given by:

$$\frac{dN_i}{dt} = \frac{dV_iC_i}{dt} = V_i\frac{dC_i}{dt} + C_i\frac{dV_i}{dt} \tag{1}$$

where V_i is the volume of segment i (m^3) and C_i is the pathogen concentration in segment i (pathogens m^{-3}). The first term on the right-hand side of equation 1 can be rewritten as:

$$\begin{aligned} V_i\frac{dC_i}{dt} &= \sum_j (Q_{ij}C_j - Q_{ij}C_i) + \sum_j E_{ij}^*(C_j - C_i) \\ &\quad + \sum_{R_i(t)} IM_fP + \sum_{R_i(t)} IFM_{AFR}P \\ &\quad - kC_iV_i \pm v_EA_{EH}C_i - v_HA_{EH}C_i \end{aligned} \tag{2}$$

where Q_{ij} refers to net flow between segments i and j ($m^3\ d^{-1}$). E^* is a bulk exchange coefficient describing dispersive flux between segments i and j ($m^3\ d^{-1}$). I is the age-weighted infection rate, M_f is the mass of fecal material shed by a recreator (g recreator^{-1}). P is the pathogen content of the fecal material (pathogens g^{-1}). F is the AFR frequency, M_{AFR} is the mass of AFR (g recreator^{-1}), k is the inactivation rate constant for the pathogen (d^{-1}), v_E is the epilimnetic settling velocity of the pathogen ($m\ d^{-1}$), A_{EH} is the cross-sectional area for epilimnion–hypolimnion exchange (m^2), and v_H is the hypolimnetic settling velocity ($m\ d^{-1}$). The inputs from fecal shedding and AFRs are summed over $R_i(t)$, the number of recreators on segment i per day (recreators d^{-1}).

The bulk exchange coefficient E^* is given by:

$$E_{ij}^* = \frac{E_{ij}A_{ij}}{\Delta X_{ij}} \tag{3}$$

where E_{ij} is an effective dispersion coefficient ($m^2\ d^{-1}$), A_{ij} is the interfacial area between segment i and j (m^2), and ΔX_{ij} is the distance from the centroid of i to j (m) (Thomann and Mueller, 1987).

Solution to equation 1 also requires accounting for change in volume of each segment as a function of time (dV_i/dt). The change in volume of segment i is dependent upon the net inflow or outflow to segment i, and given simply by:

$$\frac{dV_i}{dt} = \sum_j Q_{ij}. \tag{4}$$

The inlet/outlet structure of the reservoir has been designed such that inflows will be restricted to the hypolimnetic zone to maintain thermal stratification and avoid breaching of the thermocline. The tower will also be fitted with multiple tiers to allow selective withdrawal of water from within the water column, thus allowing operational flexibility to avoid possible zones of reduced water quality (e.g., HS^- in anoxic hypolimnetic zones, geosmin and/or 2-methylisoborneol in surface or subsurface waters). Accordingly, convective flow from inflow/withdrawal was restricted to the lower, hypolimnetic zone in the simulations. Hypolimnetic velocities were scaled to total inflow/withdrawal rate, and ranged from approximately 0 to ±30 m/d. Flow was assumed to radiate from the inlet/outlet tower and be directed principally toward the center of the west basin and reservoir (upon inflow), setting up a weak clockwise hypolimnetic flow in the west basin and a weak counter-clockwise flow in the east basin. Flow was assumed to reverse upon water withdrawal. Exchange between the east and west basins proceeded by convection across the interface between segments 25 and 21. Given the nature of the pathogen inputs (e.g., water skiers and jet skiers distributed across the reservoir surface, and their movement about the reservoir), and available data about wind patterns at the site, transport within the epilimnion was modeled using an effective dispersion approach. Net flows to the reservoir, as previously indicated, were assumed to vary sinusoidally, with net inflows occurring from January through June, and withdrawals from July through December. A maximum inflow of 1700 acre-feet/day was assumed in the simulations, and occurred at the end of March. A corresponding maximum outflow of 1700 acre-feet/day was assumed to occur at the end of August.

The model was used to estimate pathogen concentrations in the reservoir under a proposed recreational scenario which included boating, water skiing, and PWC use. Recreational use was assumed to vary seasonally based on statistics from the California Boating Association and usage data for nearby Lake Perris. Daily use levels are shown in Fig. 2.

Monte Carlo analyses

Individual recreator pathogen inputs. Monte Carlo techniques were incorporated into the finite segment model so that the occurrence of infection and AFRs, mass of feces shed, mass of AFR, pathogen content of feces, and location on the reservoir was evaluated for each recreator and conformed only in the ensemble-averaged sense to the population-averaged infection rate, AFR frequency, and other statistics. For example, assuming some age-weighted infection rate for the recreator population, MC was used to test the infection state of each recreator such that the ensemble-averaged infection rate was equivalent to a population average value without specific assumptions about individual recreators. MC techniques were also used to define individual recreator shedding characteristics (e.g., fecal shedding rate, pathogen content) which could be expected to vary significantly across the recreator population. This is depicted graphically in flowchart form in Fig. 3 and described in more detail in the following paragraphs.

For each day during the simulation period, the total number of recreators participating in body-contact recreation was determined (Fig. 2). Each recreator was then tested for infection by randomly drawing a real number between 0–1 and determining whether that number lies within an interval defined by the age-weighted infection rate for the recreator population. A recreator age distribution was used where about 4% of the recreators were <7 years of age, approximately 6% of the recreators were 7–11 years old, about 15% of the recreators were 12–17 years of age, and approximately 75% were adults age 18 years and older. The projected age distribution was provided by recreational consultants to MWD. It was important to estimate an age-weighted infection rate due to the sharply contrasting reported incidence of infection between young children and adults for many pathogens (Sealy and Shuman, 1983; Champsaur et al., 1984; Rodriquez et al., 1987; Soave and Weikel, 1990; Ungar, 1990). If the recreator was found to be non-infected, additional recreators were tested until all recreators projected to be participating in body-contact recreation that day in the simulation were evaluated. If a particular recreator was infected, then further MC tests were performed to define shedding characteristics. Each infected recreator was assigned a fecal shedding rate by using MC to randomly sample shedding rate from within an assumed distribution. Individual fecal shedding rates were assumed to follow a bounded log-normal distribution about the population mean value. Assuming a nominal population median value of 0.1 g/person, calculated from data from Rose et al. (1991a,b) and Feachem et al. (1983), individual shedding rates were allowed to range from 0.001 to 10 g/person. The distribution about the median value was such that these limits (0.001 and 10 g/person) occurred less than 1% of the time (corresponding to approximately 3 standard deviations).

Following assignment of a mass of feces shed by an individual, the pathogen content of the feces was determined. The pathogen content of feces was also assumed to vary amongst individual recreators. Pathogen contents were dependent upon the particular agent and were assumed to vary log-normally about a population median value.

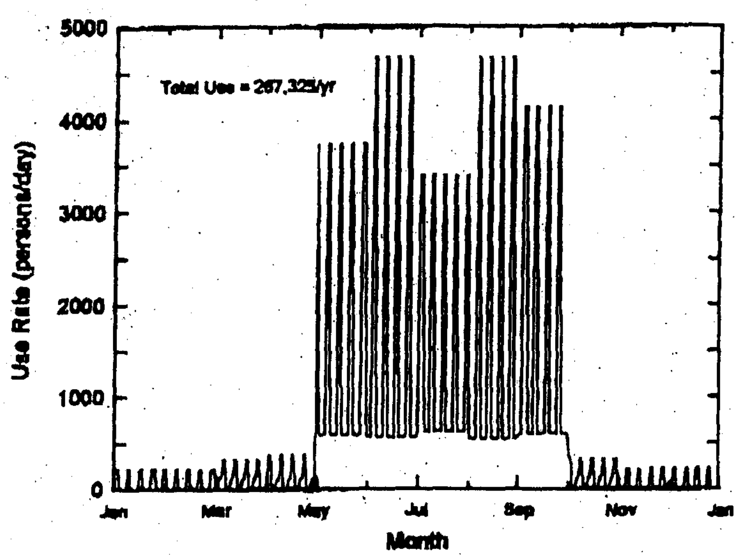

Fig. 2. Projected recreator use as a function of time of year.

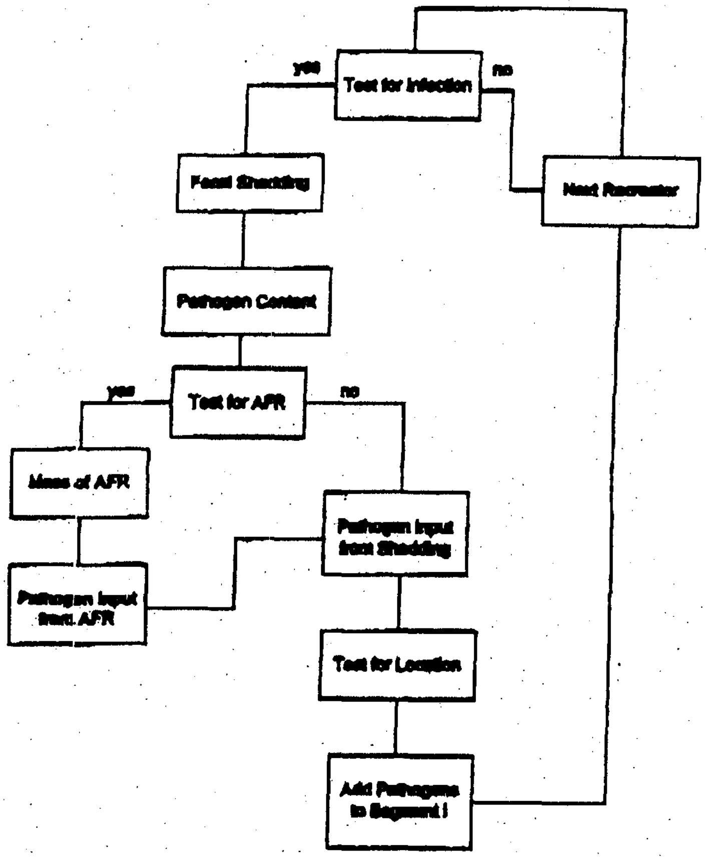

Fig. 3. Flowchart describing recreator analysis.

Cryptosporidium and *Giardia* contents of feces were assumed to vary log-normally about a median value of 10^6 oocysts/g feces (Jakubowski, 1984; Robertson *et al.*, 1995), with contents $\leq 10^5$ and $\geq 10^7$ oocysts/g occurring less than 1% of the time. Rotavirus content of feces was assumed to vary log-normally about a nominal population median value of 10^8 pfu/g (Flewett, 1982), with contents of $\leq 10^7$ and $\geq 10^9$ occurring less than 1% of the time. Poliovirus contents varied about a median value of 10^7 pfu/g with a range of 10^6–10^8 pfu/g feces (Melnick and Rennick, 1980).

The recreator was then tested for an AFR in a fashion similar to that used to establish infectivity. Approximately 1 in 1000 recreators were assumed to contribute an AFR to the water column. If positive, mass of AFR was randomly assigned from a uniform distribution which varied from 50–200 g/AFR (Feachem *et al.*, 1983; Bitton, 1994). This, combined with the previously determined pathogen content of feces, was used to define the pathogen input from an AFR. The pathogen input from fecal shedding was then summed with AFR input, if present, to yield the total pathogen input due to that recreator.

The final step involved placing the recreator on the reservoir. The pathogen input was randomly assigned to a segment subject to two constraints. The first constraint was that no recreational activity was allowed within segment 37, or within about 300 m of the outlet tower. Additionally, the probability of a recreator on a particular segment was normalized to the segment surface area: total available surface area ratio (e.g., the probability of a recreator on segment 22 was lower than that for the neighboring larger segment 21). Recreator densities will likely exhibit some regularities in spatial distribution, e.g., higher densities near the launch lanes, but these effects were not considered in this study.

Uncertainty analysis. Preliminary efforts at predicting the impacts of recreation on pathogen concentrations in the reservoir used an average-case/worst-case approach, where median and high-end values reported in the literature were used as model parameters in the simulations. Sensitivity analysis about the average case parameter set demonstrated that the model was strongly sensitive to a number of model parameters, including mass of feces shed (M_f), frequency and mass of AFRs (F and M_{AFR}, respectively), pathogen content of feces (P), and inactivation rate (k). Considerable variability exists in the literature for many of these parameters, and in some instances, limited information was available. Accordingly, an uncertainty analysis was conducted in which multiple simulations were performed using population or global parameter values randomly

Table 1. Input parameters used in Monte Carlo analysis

Parameter	Distribution	*Cryptosporidium*	Rotavirus	*Giardia*	Poliovirus
Infection Rate (%)	uniform	0–5	5–20	0–10	5–20
Feces shed (g person)	log-uniform	0.01–1	0.01–1	0.01–1	0.01–1
Pathogen content of feces (g^{-1})	log-uniform	10^5–10^7	10^7–10^9	10^5–10^7	10^6–10^8
AFR frequency (per 1000)	uniform	0–2	0–2	0–2	0–2
Mass of AFR (g AFR)	uniform	50–200	50–200	50–200	50–200
Inactivation rate-epilimnion (d^{-1})	uniform	0.016–0.15	0.1–0.5	1.1–1.65	0.28–0.88
Inactivation rate-hypolimnion (d^{-1})	uniform	0.008–0.020	0.05–0.25	0.04–0.13	0.14–0.44

selected from within defined ranges based upon literature values and expert consensus (Table 1).

The rate of infection varies with the type of pathogen and the age of the individual (Fox and Hall, 1980; Howell and Waldron, 1978; Monto *et al.*, 1983; Sealy and Shuman, 1983; Champsaur *et al.*, 1984; Ungar, 1990; Soave and Weikel, 1990). The mass of feces shed by recreators were estimated from graywater studies in which the number of fecal bacteria shed during bathing were quantified (Rose *et al.*, 1991a,b) and combined with the reported concentrations of fecal bacteria per g of feces (Feachem *et al.*, 1983). Pathogen content of feces were taken from reported values (Melnick and Rennick, 1980; Flewett, 1982; Jakubowski, 1984; Robertson *et al.*, 1995). The frequency at which AFRs occur in recreational settings was not reported in the literature, although informal interviews with lifeguards, pool maintenance staff and others suggest it is relatively common among young children.

The range in pathogen inactivation rate constants (Table 1) were taken from reported values in the literature (Bingham *et al.*, 1979; Hurst and Gerba, 1980; Raphael *et al.*, 1985; Hurst *et al.*, 1989; Robertson *et al.*, 1992; Gerba *et al.*, 1993; Carrington and Ransome, 1994) and allowed to vary for the epilimnion and hypolimnion during the summer due to the strong temperature differential that exists during thermal stratification. It was assumed that the summer epilimnetic and hypolimnetic temperatures were approximately 25 and 10°C, respectively (Lund *et al.*, 1994). During the winter, well-mixed conditions were assumed, with the inactivation rate in the upper 6 m of the water column lowered to that of the hypolimnion. Protozoa were also assumed to be removed from the water column by sedimentation (equation 2). Hypolimnetic settling velocities of 0.025 and 0.10 m/d were assumed for *Cryptosporidium* and *Giardia*, respectively, based upon downward revisions to Stokes velocities. Settling velocities in the well-mixed epilimnion were assumed to be 25 times lower than the respective hypolimnetic velocities. Based upon the comparatively higher rates of inactivation as compared to these settling velocities, sedimentation accounted for only a few percent of the total protozoan loss from the water column in these simulations.

Estimates of recreational use were also allowed to deviate from the projected levels by up to 50%. Longitudinal and transverse dispersion coefficients were estimated based upon wind speed measurements at the reservoir site and values reported in the literature, and were allowed to range from 6×10^5–6×10^6 m^2/d and 3×10^5–3×10^6 m^2/d, respectively. Water column temperature data from a nearby reservoir were used to estimate a median

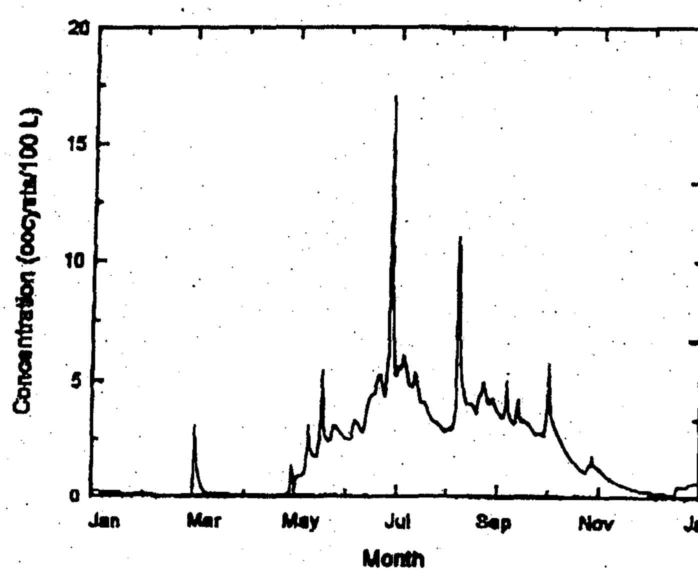

Fig. 4. Predicted concentration of *Cryptosporidium* at the outlet tower from an arbitrary simulation.

hypolimnion–epilimnion exchange coefficient during summer stratification of 0.1 m^2/d, which was allowed to vary from 0.03–0.3 m^2/d for a given simulation (Thomann and Mueller, 1987).

Five thousand simulations were conducted for each of the pathogens using randomly selected, uncorrelated parameter sets (Table 1). A variable timestep, fourth-order Runge–Kutta scheme was used to numerically integrate the governing equations (equations 1–3). Numerical losses were less than 4% and generally less than 1% over the course of a simulated 1-year interval. Two-year simulations were conducted for each parameter set, with the first year used to condition the system and eliminate any influence of initial conditions. The second year results were then stored for subsequent analysis. Calculations were performed on a DEC Alpha 250/4 266 workstation (Digital Equipment Corporation, Maynard, MA).

RESULTS

The model predicted pathogen concentrations throughout the reservoir which varied considerably over space and time. Particular interest was placed on the concentration at the outlet tower, which could then be used with estimates of transport time to treatment plants and the inactivation rate constant to predict concentrations reaching the plants.

Epilimnetic concentrations of pathogens at the outlet tower (and throughout the reservoir) were predicted to be lower during the winter when compared to the high use summer months (e.g., Fig. 4). It was assumed in the model that stratification of the reservoir commenced at the very end of April and persisted into December. Thus recreational use during this time resulted in significant pathogen loading which was chiefly confined to the epilimnion. An important feature of Fig. 4 (and results from other simulations) is the presence of temporally high concentrations, wherein the concentration at the outlet increased sharply from some baseline level, and then rather quickly returned to the baseline level. Randomizing pathogen inputs amongst the epilimnetic segments approximates the release of pathogens by infected individuals located at various points on the reservoir (e.g., a water skier entering the water at some location on the reservoir). Specifically, high concentration spikes arise from an AFR from an infected individual in a segment adjacent to the outlet tower segment, while lower concentrations result from shedding near the outlet tower and from AFRs by infected individuals at increasing distances from the outlet tower.

The probability of a high concentration spike from an AFR in any given year can be readily calculated. Consider the scenario in Fig. 4 further. Assuming an age-weighted infection rate for *Cryptosporidium* of 2.5% and an age-weighted AFR frequency of about 0.1% or 1 person in 1000, the probability of an AFR from an infected individual, then, is 0.0025% of the recreator population. If approximately 268,000 recreators enter the water in a given year, then, on average, only about 7 individuals will have AFRs and be infected and consequently shedding *Cryptosporidium*. Those 7 individuals can then be located in any of 37.38 different segments (recreators are excluded from segment 37, i.e., immediately adjacent to the outlet tower); on average, then, it would be anticipated that approximately 1 AFR every 2 years would occur at one of the 3 segments bounding the reservoir outlet (Fig. 1). Because these calculations are completely randomized, a result from a single simulation bears no particular significance, and the results only conform to the population statistics for the ensemble average. As a result, 5000 simulations were conducted and the results were statistically analyzed for this larger sample.

Annual average concentrations

Results from such an analysis comparing annual average *Cryptosporidium*, *Giardia*, rotavirus and poliovirus concentrations at the outlet tower are provided in Fig. 5. Annual average epilimnion concentrations were determined for simulations using randomly selected input parameter sets (Table 1) and recreator characteristics (Fig. 3). The resulting predicted concentrations for each pathogen were then sorted and the cumulative distribution function (cdf) developed (Fig. 5). Predicted protozoan concentrations at the outlet tower were lower than virus concentrations at equivalent probabilities, with particularly high concentrations predicted for rotavirus. Median concentrations increased from 0.01 cyst/100 L for *Giardia* to 0.27 oocyst/100 L for *Cryptosporidium* and 1.82 and 85.13 pfu/100 L for poliovirus and rotavirus, respectively. Predicted virus concentrations spanned approximately 2 orders of magnitude over the 1–99% probability range, while protozoan concentrations exhibited more variability (approximately 3 orders of magnitude) which can be attributed in part to the higher variability in reported input parameters.

During the winter months (December–April) when the reservoir was well-mixed, hypolimnetic concentrations followed very closely the concentrations of the epilimnion and were generally quite low. Stratification effectively isolated the lower portions of the water column from pathogen inputs, so pathogen concentrations in the hypolimnion remained low during the summer months as well. Inputs to the hypolimnion due to dispersive flux (and sedimentation for the protozoa) were in all simulations a very minor process, accounting for no more than a few percent of the pathogens input to the epilimnion. As a result, predicted annual average concentrations of pathogens near the outlet tower in the hypolimnion were 10–1000 times lower than those observed for the epilimnion (Fig. 6). The

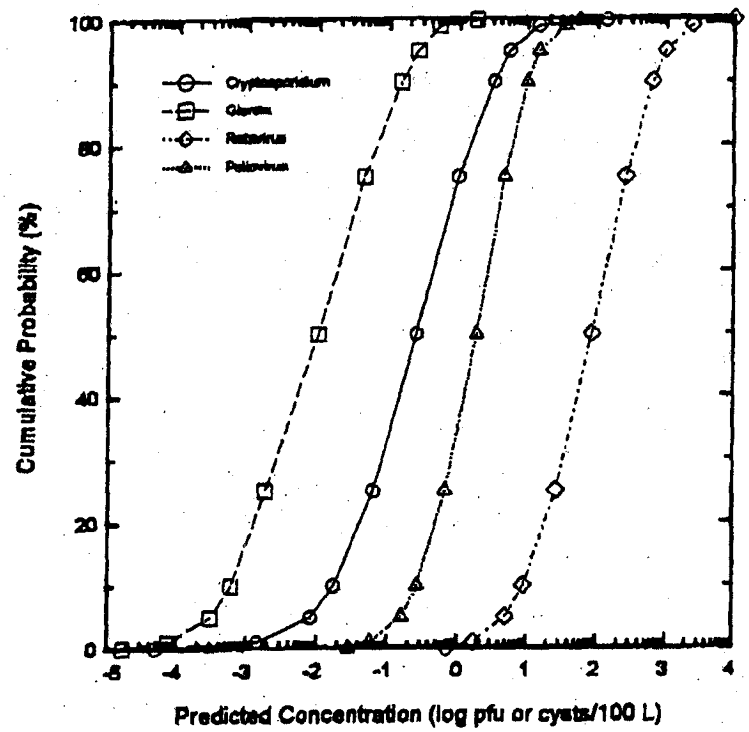

Fig. 5. Cumulative probability distribution function for predicted annual average epilimnetic pathogen concentrations.

relative ordering of pathogens in the cdf also changed from that in the epilimnion to *Giardia* < poliovirus < *Cryptosporidium* < rotavirus.

The predicted concentrations were generally on the low side of pathogen concentrations reported in surface waters (Rose *et al.*, 1987, 1991a,b;

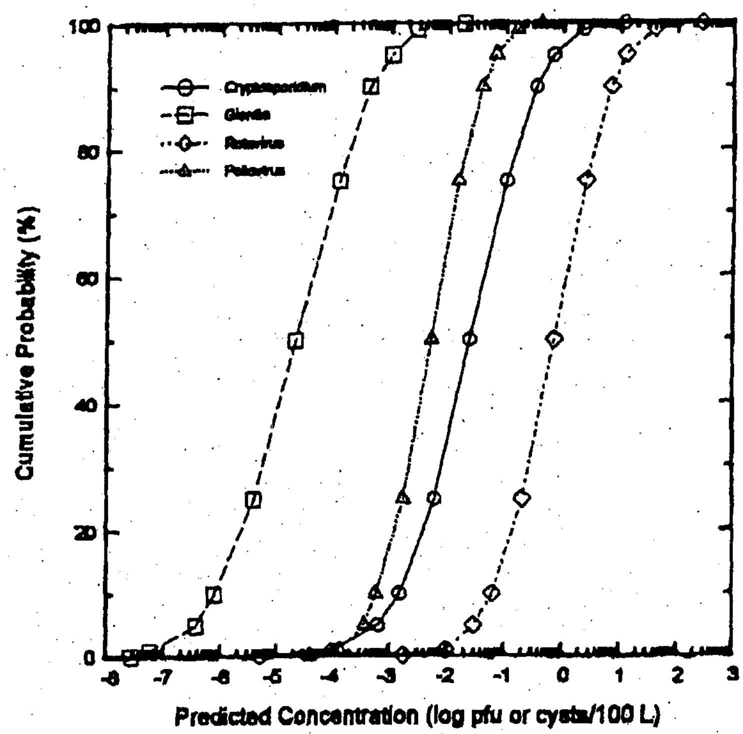

Fig. 6. Cumulative probability distribution function for predicted annual average hypolimnetic pathogen concentrations.

LeChevallier *et al.*, 1991; LeChevallier and Norton, 1995). LeChevallier and Norton (1995) reported *Giardia* cysts and *Cryptosporidium* oocysts in 53.9 and 60.2% of raw water samples, respectively, with geometric means of detectable Giardia and *Cryptosporidium* of 200–277 cysts/100 L and 240–270 oocysts/100 L (LeChevallier *et al.*, 1991; LeChevallier and Norton, 1995). The range of detectable *Giardia* and *Cryptosporidium* concentrations were quite large (2–6600 cysts/100 L and 7–48,400 oocysts/100 L, respectively). Rose *et al.* (1991a,b) reported lower geometric mean values for *Giardia* and *Cryptosporidium* than LeChevallier *et al.* (1991) and LeChevallier and Norton (1995), and summarized protozoa occurrence in surface waters as a function of surface water type. Water samples from pristine lakes were reported to have geometric mean *Giardia* and *Cryptosporidium* levels of 0.5 cysts/100 L and 9.3 oocysts/100 L, with maximum concentrations of 7 cysts/100 L and 307 oocysts/100 L, respectively. Polluted lakes had about an order of magnitude higher mean and maximum concentrations (Rose *et al.*, 1991a,b). In a study of rotaviruses and enteroviruses in recreational waters of Oak Creek, Arizona, Rose *et al.* (1987) reported enterovirus and rotavirus concentrations of about 2 and 25 viruses/100 L, respectively, in sections of Oak Creek where a significant level of recreational activity was observed, while no detectable rotavirus concentrations were found for stream reaches without recreational activity. Reservoir design (e.g., very limited watershed) and current use plans (e.g., no agricultural activities within the watershed) for the reservoir limit the potential for non-recreational pathogen inputs.

Model results can also be compared with available monitoring data for treatment plant influents from reservoirs currently in MWD's system. The reservoirs vary in allowable recreational activities, source water quality, watershed protection, and other factors, so direct comparisons with simulation results are tentative. Nevertheless, for samples collected monthly at the influents of each of five drinking water treatment plants from 10/94–12/97, 141 out of 195 samples (72%) were below detection limits for *Cryptosporidium*, while 95% of all samples were < 10 oocysts/100 L. The geometric mean for detectable *Cryptosporidium* in the influent samples was 5.0 oocysts/100 L. *Cryptosporidium* concentrations > 100 oocysts/100 L were observed in two samples (MWD, unpublished data). These data are, in general, of the same magnitude as those concentrations predicted by model simulation.

Peak concentrations

In addition to the annual average concentrations, which tend to guide treatment practice, an analysis of predicted peak events was conducted. The magnitude and frequency of these peak events also play a role in treatment considerations and affects short-term risk to water consumers. Furthermore, these peak events may also have significant negative impacts on recreators who ingest water during recreation.

As demonstrated in Fig. 4, short-term events of locally high concentrations were predicted to occur

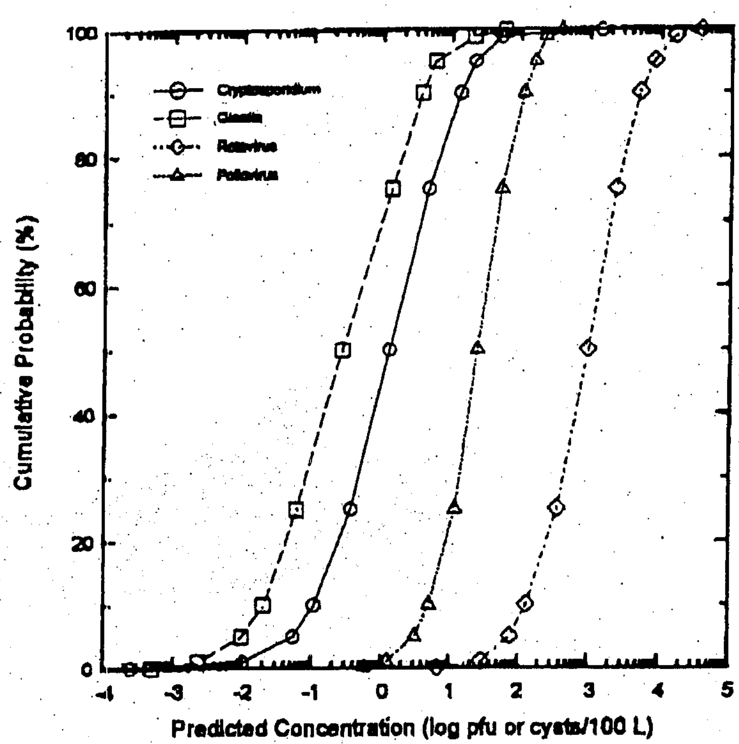

Fig. 7. Cumulative probability distribution function for peak epilimnetic concentrations.

randomly over space and time. Higher probabilities of occurrence were predicted for the high use summer months, but spikes were also occasionally predicted during the low user winter months as well (Fig. 4). An analysis similar to that for the annual average concentrations was conducted. In this case, the highest concentration observed in each year was recorded, which yielded 5000 peak concentrations. Cumulative probability distribution functions for the four pathogens under consideration in the study are presented in Fig. 7. The trends were similar to that for predicted annual average epilimnion concentrations (Fig. 5), with concentrations increasing in the order *Giardia* < *Cryptosporidium* < poliovirus < rotavirus. Peak *Cryptosporidium* concentrations were approximately 5 times higher than the annual average values (e.g., simulations yielded a median peak *Cryptosporidium* concentration of 1.26 oocysts/100 L), while peak concentrations for *Giardia*, rotavirus and poliovirus were about 20, 9 and 12 times higher than their annual average values, respectively. This approximately follows the order of inactivation rate coefficients for the different pathogens (Table 1), which suggests that the higher the inactivation rate, the larger the difference between peak and average values.

In addition to the highest concentration found each simulated year, an analysis of the frequency of these peak-type events was undertaken. Based on treatment efficiencies and acceptable consumer risk levels, a threshold pathogen concentration above which treatment may not adequately remove pathogens can be calculated. Assuming an average transport time of 12 h from the reservoir to the nearest treatment plant, an inactivation rate of $0.09\ d^{-1}$, a 3 log removal efficiency for the plant, and an acceptable annual risk of infection of 1 per 10,000, a level of *Cryptosporidium* in the reservoir < 1.05 oocysts/100 L will result in an annual risk of infection to consumers below 1 per 10,000. For this analysis, then, peak events for *Cryptosporidium* were defined as reservoir outlet concentrations > 1.05 oocyst/100 L. Analogously, assuming a median inactivation rate of $0.3\ d^{-1}$ and a 4-log removal efficiency for

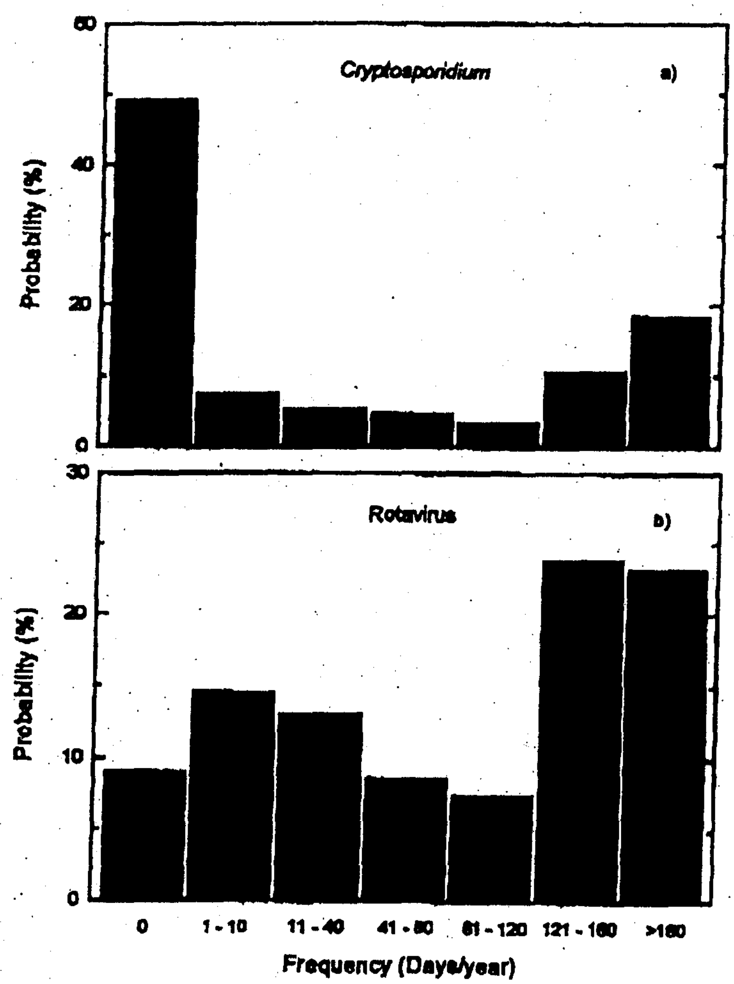

Fig. 8. Probability density function describing frequency with which daily epilimnetic (a) *Cryptosporidium* and (b) rotavirus concentrations exceeded threshold concentrations of 1.05 oocysts/100 L and 11.6 pfu/100 L, respectively.

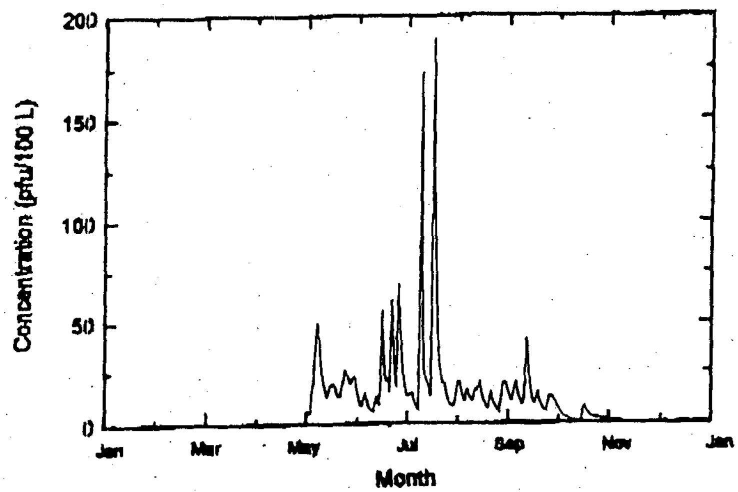

Fig. 9. Predicted epilimnetic rotavirus concentration at the outlet tower vs time of year from an arbitrary simulation.

rotavirus, peak levels were defined as concentrations > 11.6 pfu/100 L.

Based on these criteria for a peak event, simulations resulted in a wide range in peak event frequencies (Fig. 8). For *Cryptosporidium*, 50% of the simulations yielded daily concentrations that remained below 1.05 oocyst/100 L throughout the year (Fig. 8(a)). However, almost 20% of the simulations also yielded years where concentrations exceeded the threshold level of 1.05 oocyst/100 L more than 160 d/year (Fig. 8(a)). Contrasting with *Cryptosporidium*, predicted rotavirus concentrations routinely exceeded their threshold level of 11.6 pfu/100 L, with nearly 50% of the simulations exceeding this level > 120 d out of the year (Fig. 8(b)).

Implications for sampling and model validation

The model predicted mean annual average values which, in many instances, do not exceed acceptable levels based on present treatment practices. Notable, however, was the presence of transient spikes of high concentration (e.g., Fig. 4). One challenge associated with model validation lies in the requirement of sufficiently intensive sampling to catch these infrequent yet important peak events. As an illustration, the data from a rotavirus simulation (Fig. 9) was used in a hypothetical sampling of the reservoir.

Two sampling schemes at the reservoir outlet were employed: a regular, twice-monthly sampling ($n = 24$) and a random sampling scheme ($n = 24$). The results from these sampling strategies are compared with a complete ($n = 365$) sampling (Table 2). An important conclusion is that both sampling schemes underpredicted the mean as well as the variance of the population. Regular sampling underpredicted by about 20% the population mean value, while random sampling underpredicted the population value by approximately 40%. Both schemes underpredicted the standard deviation about the population mean by 50% or greater, implying considerably less variability in the pathogen concentrations in the reservoir than actually present. Perhaps more importantly, both sampling strategies missed the *two* peak events occurring in July and the *five* lesser peaks in May, June and September. The model results suggest, then, that fairly intensive sampling, whether by random or regular sampling schedules, will generally not catch the important pulses of higher pathogen concentrations that may be present at the outlet tower.

Limitations to model

While every effort was made to describe the important processes affecting pathogen fate in the reservoir, lack of necessary mechanistic information necessitated some simplifying assumptions. One important assumption pertained to the state of fecal material released to the reservoir. The model explicitly assumed that fecal material input to the water column disaggregated and dispersed pathogens throughout the segment immediately following

Table 2. Results from regular twice-monthly sampling ($n = 24$), random sampling ($n = 24$) and complete sampling ($n = 365$) for rotavirus at the outlet tower (epilimnion only) based upon data in Fig. 8

Sampling	Concentration (pfu/100 L)	
	mean ± std. dev.	range
Regular twice-monthly sampling ($n = 24$)	7.33 ± 9.81	8.53e-2-32.73
Random sampling ($n = 24$)	5.33 ± 7.07	2.62e-2-20.69
Complete sampling ($n = 365$)	9.12 ± 18.7	2.32e-2-189.0

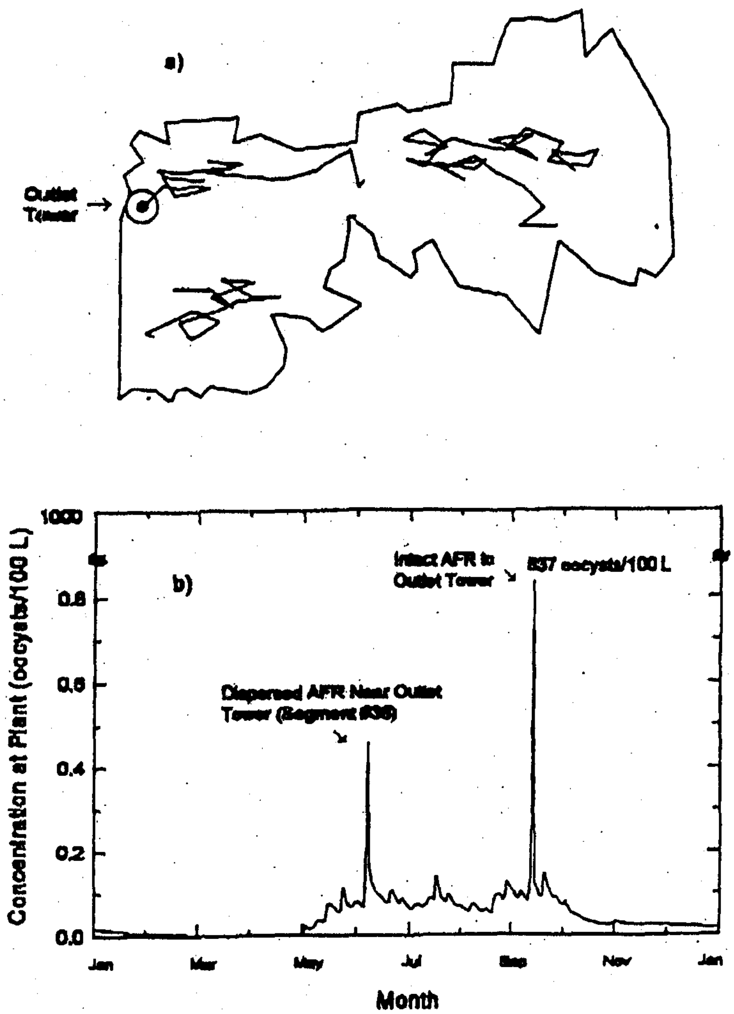

Fig. 10. Results from particle tracking model: (a) three example trajectories, and (b) predicted concentration at treatment plant contrasting dispersed and aggregated AFRs.

release. While this assumption may be adequate for shed fecal material, AFRs may remain intact for some period of time. The implications of this include: (i) possible sedimentation losses, (ii) reduction in rate of inactivation of pathogens within the fecal material, (iii) alteration of reservoir concentration and the frequency of peak events, and (iv) increased magnitude of pathogen concentrations reaching plant during a peak event.

The importance of dispersed vs intact fecal material on overall pathogen concentrations is difficult to ascertain, but some general comments can be made. First of all, for *Cryptosporidium* and rotavirus, about one-half of the predicted total pathogen input in a given year comes from shed fecal material and one-half from AFRs. Thus approximately one-half of the total pathogen load is potentially affected by these additional considerations.

To better understand the behavior of aggregated fecal material and the role it might have on pathogen transport, a simple particle tracking/random walk model was developed and superimposed on the finite segment model. The rules used for the random walk were as follows: one-half of the predicted AFRs were treated as previously described (i.e., assumed to readily disperse), while the remaining AFRs were initially assigned to random locations on the reservoir. Each AFR could travel up to ±1000 m/d in the longitudinal (east–west direction) and up to ±500 m/d in the transverse direction. Velocities were assigned assuming random uniform distributions within these intervals. The AFRs were constrained to remain within the reservoir by reflecting boundary conditions. Sedimentation was modeled assuming sedimentation velocities in the epilimnion which ranged from −0.5 to 0.5 m/d, with a reflecting upper water surface boundary. Sedimentation in the hypolimnion was assumed to proceed at velocities of 0 to 0.5 m/d.

Results of three random trajectories are shown in Fig. 10(a). In one trajectory, the AFR reaches the capture zone for the outlet tower and is assumed to be drawn out of the reservoir and transported to the treatment plant. Figure 10(b) shows

Cryptosporidium concentration at the treatment plant for two AFRs assuming epilimnetic water contributes 25% of the total flow to the treatment plant. The first AFR was dispersed (as assumed in the previous analyses) in the reservoir and yielded a peak concentration of about 0.5 oocysts/100 L, while the second AFR remained effectively intact until it was disaggregated in the process of being drawn out the outlet structure, where it resulted, in this example, in a concentration at the treatment plant of 837 oocysts/100 L. While the probability of an intact AFR reaching the outlet tower is low, such an event represents a very large input of pathogens to the treatment plant and a possible significant health risk to downstream consumers. Detailed hydrodynamic data and AFR transport and disaggregation kinetics are necessary before the importance of this transport mechanism can be fully quantified; however, some projections can be made. Assuming the recreator use pattern given in Fig. 2, an AFR frequency of 1 per 1000 recreators, with 50% of AFRs as solid, an average AFR residence time in the water column of 10 d, and infection rates of 2.4 and 13.5% for *Cryptosporidium* and rotavirus, the frequency of a solid AFR peak event is 0.07 and 0.36 yr^{-1}, respectively. Thus, recreational activity on the reservoir may result in pathogens concentrations reaching the treatment plant which are capable of causing an outbreak every 3 to 15 years.

CONCLUSIONS

The impacts of body-contact recreational activities on *Cryptosporidium*, *Giardia*, rotavirus and poliovirus concentrations in a source drinking water reservoir, presently under construction, were evaluated through a modeling study which included uncertainty analysis using a hybridized Monte Carlo-finite segment model. The model results indicate that potentially high concentrations of *Cryptosporidium*, rotavirus, and to a somewhat lesser extent, poliovirus may be present in the epilimnion during the high-use summer months. Predicted *Giardia* concentrations resulting from recreational activity were typically much lower. Hypolimnetic concentrations of all pathogens were 1–3 orders of magnitude lower than corresponding epilimnetic concentrations. A notable feature of the simulations was the presence of locally high concentrations, attributable to AFRs and multiple shedding events, which may increase pathogen levels in a segment by an order of magnitude over baseline-averaged levels. Using a definition of a peak event as a daily concentration >1.05 oocyst or 11.6 pfu/100 L for *Cryptosporidium* and rotavirus, respectively, 50% of the simulations yielded no daily peak events for *Cryptosporidium*. Rotavirus routinely exceeded this threshold, however, with almost 50% of the simulations yielding greater than 120 daily concentrations >11.6 pfu/100 L per year. Model results also suggest that field sampling will underestimate the mean, range and variance of pathogen concentrations in the reservoir. Finally, application of a particle tracking routine suggests that aggregated AFRs will result in periodic pulses of high pathogens loads to the treatment plant.

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Exhibit 13

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Sources and Species of *Cryptosporidium* Oocysts in the Wachusett Reservoir Watershed

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Understanding the behavior of *Cryptosporidium* oocysts in the environment is critical to developing improved watershed management practices for protection of the public from waterborne cryptosporidiosis. Analytical methods of improved specificity and sensitivity are essential to this task. We developed a nested PCR-restriction fragment length polymorphism assay that allows detection of a single oocyst in environmental samples and differentiates the human pathogen *Cryptosporidium parvum* from other *Cryptosporidium* species. We tested our method on surface water and animal fecal samples from the Wachusett Reservoir watershed in central Massachusetts. We also directly compared results from our method with those from the immunofluorescence microscopy assay recommended in the Information Collection Rule. Our results suggest that immunofluorescence microscopy may not be a reliable indicator of public health risk for waterborne cryptosporidiosis. Molecular and environmental data identify both wildlife and dairy farms as sources of oocysts in the watershed, implicate times of cold water temperatures as high-risk periods for oocyst contamination of surface waters, and suggest that not all oocysts in the environment pose a threat to public health.

Cryptosporidium parvum is an intracellular protozoan parasite responsible for an acute gastrointestinal and, less frequently, respiratory infection in humans that is self-limiting in immunocompetent people but prolonged and potentially life-threatening for the immunocompromised population (31). Gastrointestinal cryptosporidiosis is characterized by watery diarrhea, abdominal pain, low-grade fever (<39°C), general malaise, weakness, fatigue, loss of appetite, nausea, vomiting, and weight loss (10, 34). Symptomatic infection may last from a few days to a few weeks in immunocompetent individuals, although extreme cases of up to 12 weeks of severe diarrhea have been reported (34). Cryptosporidiosis is particularly serious for immunosuppressed people because no curative treatment currently exists.

The existence of multiple species of *Cryptosporidium*, including *C. parvum*, *C. muris*, *C. felis*, *C. wrairi*, and *C. andersoni* (mammals), *C. baileyi* and *C. meleagridis* (birds), *C. serpentis* (reptiles), and *C. nasorum* (fish), has been suggested on the basis of oocyst morphology, host specificity, infectivity, and 18S rRNA sequence comparisons (33, 34, 36). There is some uncertainty with respect to the validity of these taxa. For example, *C. wrairi* appears to be a strain of *C. parvum* that is isolated from guinea pigs, while *C. andersoni* is a recently proposed species characterized by *C. muris*-like oocysts that infect cattle (21). Classifications based on host species may not be appropriate given that *C. felis*, associated with cryptosporidial infection in cats, was recently isolated from a cow (4). There are now multiple reports of species other than *C. parvum* infecting humans, particularly immunocompromised people (12, 17, 25, 27, 28, 39). Due to the confusion surrounding the taxonomy of *Cryptosporidium*, it is difficult to conclusively assess the human public health threat attributable to *Cryptosporidium* species other than *C. parvum*.

Numerous outbreaks of waterborne cryptosporidiosis in the United States have occurred over the past 20 years (6, 31) in both rural and urban areas, spanning the nation from Pennsylvania to Oregon. *Cryptosporidium* species are a threat to water supplies because they are resistant to chlorine disinfection, small (~5 μm in diameter) and thus difficult to filter, and harbored by many animal species (10). The largest waterborne outbreak in U.S. history occurred in Milwaukee, Wis., in the spring of 1993 and affected an estimated 403,000 people served by the Milwaukee Water Works. The Wisconsin Division of Health found that the outbreak was responsible for the premature deaths of at least 69 individuals, most of whom were human immunodeficiency virus positive. The sources of oocyst contamination, although not identified conclusively, were suspected to include cattle waste, slaughterhouse waste, and human sewage. The combination of severe spring rains and snow-melt runoff that occurred just prior to the outbreak could have carried oocysts from these suspected sources into Lake Michigan and subsequently into the intakes of the Milwaukee Water Works treatment plants. Treatment processes at the South Milwaukee Water Works plant included the following: chlorine and permanganate addition at the raw water intake, polyaluminum chloride coagulation, rapid mixing, flocculation, sedimentation, rapid sand filtration, chlorination, and fluoride addition. Despite such thorough water treatment, the turbidity of the South Milwaukee Water Works plant effluent exceeded the 1993 Environmental Protection Agency (EPA) limit of 1.0 nephelometric turbidity unit(s) (NTU), peaking at 1.7 NTU in late March 1993 (10, 23, 31)

This episode of *Cryptosporidium* oocysts passing through a water treatment plant bolsters the argument that successful public health measures must include appropriate watershed

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management. Improved watershed management requires a better understanding of the behavior of *Cryptosporidium* oocysts in the environment, and this in turn requires improved analytical detection methods. We now report a sensitive and specific nested-PCR–restriction fragment length polymorphism (PCR-RFLP) assay for detection of *Cryptosporidium* oocysts in environmental samples. This nested PCR targets a 434-bp hypervariable region of the 18S rRNA gene, a multicopy gene (20 copies per oocyst) ideal for species identification. Application to surface water and animal fecal samples from the Wachusett Reservoir watershed in central Massachusetts confirms the method's high degree of sensitivity and specificity and provides new hypotheses regarding the control of *Cryptosporidium* oocyst contamination in surface waters.

Molecular methods for detection of *Cryptosporidium* oocysts in wastewater and surface water have been reported (22, 38, 40), and we have extended these studies with the development of a novel assay and its application to the investigation of sources and species of oocysts in a geographic area that has not been previously described. The Wachusett Reservoir, a drinking water source for Boston, Mass., and surrounding cities, has recently been the subject of litigation concerning appropriate measures to protect against waterborne parasites such as *C. parvum* and *Giardia lamblia*. Our goal of understanding the sources, species, and seasonal trends of oocyst contamination in watersheds will contribute to the development of better watershed management practices to prevent waterborne outbreaks of cryptosporidiosis in drinking water watersheds.

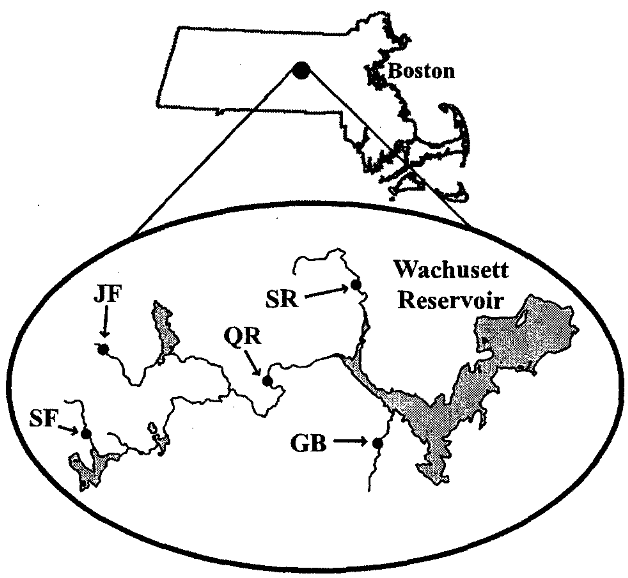

FIG. 1. Schematic of the Wachusett Reservoir watershed sampling sites in central Massachusetts. Abbreviations: SR, Stillwater River; QR, Quinapoxet River; GB, Gates Brook; SF, Brook SF; JF, Brook JF. Suspected sources of oocyst contamination include wildlife (SR and QR), sewage (GB), and agricultural runoff from dairy farms (SF and JF).

MATERIALS AND METHODS

Oocysts. GCH1 *C. parvum* oocysts were a kind gift of Giovanni Widmer at Tufts University School of Veterinary Medicine in North Grafton, Mass.

Surface water sample selection. Sampling sites in the Wachusett Reservoir watershed in central Massachusetts (Fig. 1) were chosen to encompass a variety of potential sources of *Cryptosporidium* contamination. Surface water sites (and their suspected source of contamination) included Stillwater River (wildlife); Quinapoxet River (wildlife); Gates Brook (sewage); and two small, unnamed brooks, designated Brook JF and Brook SF, downgradient from dairy farms (agricultural runoff). Stillwater River and Quinapoxet River were sampled monthly from February 2000 to January 2001, often side-by-side with the Metropolitan District Commission (MDC) of the Commonwealth of Massachusetts. The MDC adhered to the Information Collection Rule (9), using conventional yarn-wound filters and an immunofluorescence microscopy assay (IFA) for oocyst detection. Gates Brook, Brook JF, and Brook SF were sampled periodically, but not as frequently, from March 1999 to January 2001.

Sample collection. Surface waters were filtered through Gelman Envirochek Sampling Capsules (Pall Gelman Sciences, Inc., Ann Arbor, Mich.) at 1 to 2 liters min^{-1} according to manufacturer's recommendations. During filtration, water temperature was recorded. Filtration continued for 1 h or until the backpressure exceeded the filter rating (30 lb/in^2 [psi]), whichever came first. Typically, 40 to 80 liters of water were filtered. Filters were transported to the laboratory on ice, and samples were eluted according to manufacturer's recommendations within 36 h of sample collection. Eluted solids were resuspended in 10 ml of laboratory-grade water (Milli-Q System; Millipore Corp., Bedford, Mass.) for each 0.5 ml of solids, stored at 4°C, and processed within 24 h.

Fecal samples were collected in sterile 50-ml polypropylene tubes and transported to the laboratory on ice. Fecal samples were suspended in 10 ml of laboratory-grade water for each 0.5 ml of solids, stored at 4°C, and processed within 24 h of collection.

Immunomagnetic separation of oocysts. Oocysts were purified from water and fecal samples by using immunomagnetic separation (IMS) with the Crypto-Scan IMS kit (ImmuCell, Portland, Maine) according to the recommendations of the manufacturer. After being dissociated from magnetic beads, oocysts were transferred to a new microcentrifuge tube and treated with 5 μl of 1 N NaOH to neutralize the pH. The oocysts were pelleted for 2 to 3 min at 16,000 × *g*, resuspended in 50 μl of laboratory-grade water, and stored at 4°C.

Positive and negative IMS controls were processed with each set of field samples. Positive IMS controls consisted of 9.9 ml of laboratory-grade water and 100 μl of a 10^4 oocyst ml^{-1} suspension; negative IMS controls consisted of 10 ml of laboratory-grade water. IMS controls were processed as described above.

Genomic DNA extraction. Oocysts were lysed by adding 25 μl of IMS product to 475 μl of Tris-EDTA (TE) buffer containing 0.2 g of proteinase K $liter^{-1}$ and 0.4% sodium dodecyl sulfate and incubating the mixture overnight at 45°C. Positive and negative DNA extraction controls were included for each set of field samples. Positive DNA extraction controls consisted of 25 μl of a suspension of 10^4 oocysts ml^{-1} in 475 μl of TE buffer; negative DNA extraction controls consisted of 25 μl of laboratory-grade water in 475 μl of TE buffer. DNA was extracted several times with phenol-chloroform, precipitated with 0.2 M NaCl and 2 volumes of absolute ethanol, and resuspended in 30 μl of TE buffer.

Nested PCR assay. PCR amplification was performed in a 50-μl volume containing 10 mM Tris-HCl, 50 mM KCl, 0.1% Triton X-100, 2 mM $MgCl_2$, 0.015 mM concentrations of each deoxynucleoside triphosphate (Perkin-Elmer, Wellesley, Mass.), 0.2 μM concentrations of each primer, and 2 U of *Taq* DNA polymerase (Promega Corp., Madison, Wis.). The initial amplification reaction was performed with 15 μl of DNA template, and 3 μl of the initial amplification product was used as a template for the secondary PCR. Positive and negative PCR controls were included with each set of samples. For the initial amplification reaction, positive PCR controls contained 12 μl of laboratory-grade water and 3 μl of genomic *C. parvum* DNA (at a concentration equivalent to 10^4 oocysts μl^{-1}); negative PCR controls contained 15 μl of laboratory-grade water. For the secondary amplification reaction, positive PCR controls contained 3 μl of genomic *C. parvum* DNA (at a concentration equivalent to 10^4 oocysts μl^{-1}); negative PCR controls contained 3 μl of laboratory-grade water.

Both amplification reactions used forward and reverse oligonucleotide primers that are complementary to *Cryptosporidium* 18S rRNA gene sequences (Fig. 2). The initial 1,056-bp product was obtained with a forward primer, KLJ1 (5′-CCACATCTAAGGAAGGCAGC-3′), corresponding to nucleotides 389 to 408, and a reverse primer, KLJ2 (5′-ATGGATGCATCAGTGTAGCG-3′), corresponding to nucleotides 1422 to 1441 of *C. parvum* L16996 in GenBank (3). The final 434-bp product was obtained by using forward and reverse primers CPB-DIAGF and CPB-DIAGR, respectively (16). Cycling conditions consisted of an initial denaturation (5 min at 80°C, followed by 30 s at 98°C), 40 cycles of amplification (denaturation for 30 s at 94°C, annealing for 30 s at 53°C, and extension for 1 min at 72°C), and a final extension (10 min at 72°C). Secondary

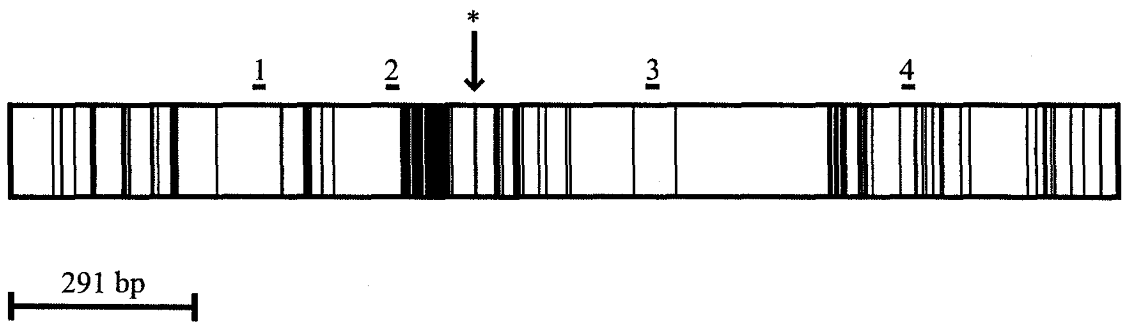

FIG. 2. Schematic of the 1,746-bp *Cryptosporidium* 18S rRNA gene (based on GenBank accession no. L16996). Within the gene, dark areas are regions of sequence variability, and white areas are regions of sequence conservation. Primer binding locations are indicated above the gene (1, KLJ1; 2, CPB-DIAGF; 3, CPB-DIAGR; 4, KLJ2). An asterisk identifies the *Nde*I digest site.

PCR products were visualized after electrophoresis on a 1.2% agarose gel stained with ethidium bromide.

RFLP analysis. Digestion of amplified 18S rRNA gene products with *Nde*I can be used to differentiate most *C. parvum* isolates from other *Cryptosporidium* species. The 434-bp final amplicon of most *C. parvum* isolates (with the exception of GenBank accession numbers AF112570 and AF108860, isolates from a kangaroo and a koala in Australia, respectively, and AF112576, the dog genotype) contains a single *Nde*I site (Fig. 2), while the amplicons from other *Cryptosporidium* species (*C. muris*, *C. baileyi*, *C. serpentis*, and *C. felis*) do not. Restriction digestion was carried out in a 20-μl volume containing 10 μl of secondary PCR product, 20 U of *Nde*I (New England Biolabs, Beverly, Mass.), 100 mM NaCl, 50 mM Tris-HCl, 10 mM $MgCl_2$, 1 mM dithiothreitol, and 100 μg of bovine serum albumin ml^{-1} and then incubated at 37°C for 1 h. Digestion products were visualized after electrophoresis on a 1.2% agarose gel stained with ethidium bromide.

Cloning. Secondary PCR products from water or fecal samples positive for *Cryptosporidium* were cloned into the pGEM-T Easy Vector System (Promega) and used to transform XL1-Blue *E. coli* cells (Stratagene, La Jolla, Calif.). Clones were selected on Luria-Bertani (LB) agar supplemented with 100 μg of ampicillin ml^{-1} and cultured overnight in LB broth supplemented with 100 μg of ampicillin ml^{-1}. Plasmid DNA was isolated from clones by using the QIAPrep Spin Miniprep Kit (Qiagen, Inc., Valencia, Calif.) and digested with *Not*I (New England Biolabs) to verify the presence of the secondary PCR amplicon insert. Plasmids with the insert were further digested with *Nde*I. All digestion products were visualized after electrophoresis on a 1.2% agarose gel stained with ethidium bromide.

Sequencing. Representative clones of the secondary PCR products were sequenced on an ABI Prism 310 Genetic Analyzer (PE Applied Biosystems, Foster City, Calif.) by using a Big Dye Terminator Cycle Sequencing Ready Reaction Kit with the AmpliTaq DNA Polymerase, FS (PE Applied Biosystems). If multiple *Nde*I digestion patterns existed among clones from a given sample, at least one clone of each digestion pattern was sequenced. At least two clones for each positive sample were sequenced in any case and confirmed by sequencing both strands. The basic local alignment search tool (BLAST) algorithm was used to compare cloned DNA sequences with GenBank sequences and to determine the species of *Cryptosporidium* present in the sample (1, 3). Multiple sequence alignments and phylogenetic trees were generated with MacVector 7.0 (Genetics Computer Group, Madison, Wis.) with manual adjustment.

RESULTS

By seeding PCRs with known quantities of oocyst DNA, initial PCR amplification of the 18S rRNA gene was found to detect as few as 500 oocysts; the lower limit of detection of nested PCR was a single oocyst (Fig. 3). This detection limit assay, however, was performed under ideal conditions and did not account for the possible presence of PCR inhibitors in environmental samples. The potential for PCR inhibition was tested by processing two filters side-by-side for a single surface water source: one filter contained the surface water only, and the second filter contained the surface water seeded with 500 *C. parvum* oocysts. Using one-half of the eluted water pellets for IMS, one-half of the IMS products for DNA extraction, and one-thirtieth of the DNA extract for PCR, the initial PCR of the seeded sample received the DNA equivalent of 4.2 oocysts. After the secondary amplification reactions, no oocysts were detected in the surface water sample alone; oocysts were clearly detected in the spiked surface water sample (Fig. 4).

For the year spanning February 2000 to January 2001, 34 surface water samples were collected for *Cryptosporidium* detection and 5 (14.7%) were determined to be positive by nested PCR. In addition, 44 water samples were collected by the MDC and 5 (11.4%) were found to be positive by IFA. Table 1 includes all of the surface water samples that were determined to be positive for *Cryptosporidium* by either nested PCR or IFA and two additional samples analyzed in March and July of 1999. Of the seven samples determined to be positive by nested PCR, *C. parvum* was identified in three samples (samples 2/1/00, 4/4/00, and 11/7/00). Sample 2/1/00 was a mixed population of *C. parvum* and *C. muris*, and *C. muris* appeared to be more prevalent since only one of the 12 clones could be digested with *Nde*I (the single clone containing an *Nde*I site was sequenced and identified as *C. parvum*, and 2 of the remaining clones were identified as *C. muris*). *C. muris* and *C.*

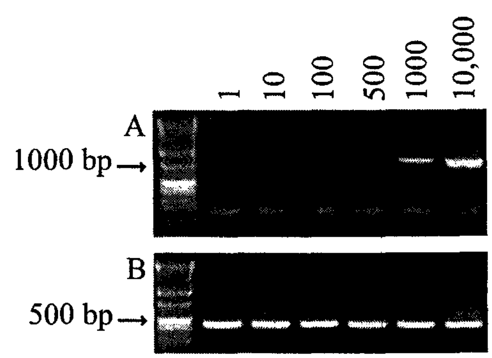

FIG. 3. Detection limit of nested PCR assay. (A) Initial PCR products (primers KLJ1/2). (B) Secondary PCR products (primers CPB-DIAGF/R). PCRs were seeded with known quantities of DNA representative of 1 to 10,000 oocysts (as indicated at the top of each lane). Corresponding lanes on gels A and B represent the same seeded sample. The first lanes of gels A and B are molecular weight standards.

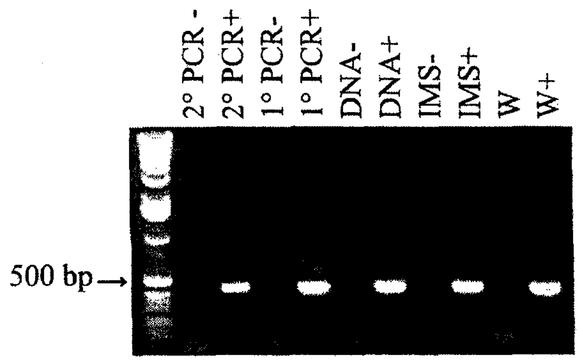

FIG. 4. The potential for PCR inhibition was tested by seeding a surface water sample with 500 oocysts. From left to right, the lanes are as follows: molecular weight standard; negative and positive controls for secondary (2°) PCR, respectively; negative and positive controls for initial (1°) PCR, respectively; negative and positive controls for DNA extraction, respectively; negative and positive controls for IMS, respectively; surface water sample (W); seeded surface water sample (W+).

baileyi were identified in three and one of the seven positive samples, respectively. One positive sample could not be cloned and sequenced due to insufficient sample quantity.

Agricultural and wildlife fecal samples were collected in June and August of 2000. Results are summarized in Table 2. Among wildlife samples, *C. parvum* was found only in fresh deer feces, and *C. baileyi* was identified in the feces from cormorants alone. No *Cryptosporidium* spp. were isolated from adult cattle on farm SF or from calves on farm JF. *C. baileyi* and *C. muris* were identified in adult cattle and in the manure pit, respectively, on farm JF.

DISCUSSION

Nested-PCR targeting the variable region of the 18S rRNA gene enabled detection of a single *Cryptosporidium* oocyst (Fig. 3); this compares favorably to other sensitive PCR-RFLP methods for detection of *Cryptosporidium* (16, 22). Given a 50% infective dose of 132 oocysts (7), our nested PCR should allow detection of oocysts in environmental samples at and below infectious levels. For all water and fecal samples that tested positive for *Cryptosporidium* oocysts, nested PCR was necessary for detection (i.e., no signal was detected in any sample after initial PCR amplification). Our findings suggest that single PCR, which has been used for both laboratory and environmental samples (2, 16, 19, 20, 22, 26, 32), may not be sensitive enough for detection of commonly occurring levels of oocyst contamination in the environment.

This *Cryptosporidium* detection assay offers a high degree of sensitivity and species-level oocyst identification. Although the assay does not provide information about oocyst viability, detection of any *C. parvum* oocysts in environmental samples from source water watersheds is a warning that precautionary measures should be considered to protect public health. Oocyst viability is influenced by many environmental factors, including temperature, hydration, starvation, predation, and UV exposure (8, 14, 24, 29). The presence of oocysts in the environment, even if nonviable at one time, is an indication that potentially viable oocysts may be present under different environmental conditions in the future.

We were able to detect multiple species of *Cryptosporidium* oocysts in water and fecal samples, including *C. parvum*, *C. muris*, and *C. baileyi* (Tables 1 and 2). The 434-bp secondary PCR product is ideal for species identification because it spans the most hypervariable region of the 18S rRNA gene but also includes recognizable, conserved anchors (Mitchell L. Sogin, personal communication).

U.S. EPA Method 1622 for *Cryptosporidium* analysis in water (35) uses IFA for detection of oocysts in environmental samples. Comparison of our results to those obtained by IFA illustrates that IFA may not be a reliable indicator of public health risk (Table 1). First, IFA results are based on visual identification of oocysts and do not classify the *Cryptospo-*

TABLE 1. Surface water samples that tested positive for *Cryptosporidium* spp.

Sample (date)[a]	Location	Sample identification	MDC[b]	Molecular results: Nested PCR	*Nde*I digest[c]	Sequence results[d]
3/1/99	Brook SF	SF	ND[e]	+	−	3/*C. muris*
7/12/99	Quinapoxet River	QR	+	+	−	3/*C. muris*
2/1/00	Stillwater River	SR	ND	+	1/+	1/*C. parvum*
					11/−	2/*C. muris*
2/22/00	Quinapoxet River		+	−		
3/7/00	Quinapoxet River		+	ND		
4/3/00	Quinapoxet River		+	ND		
4/4/00	Gates Brook	GB	ND	+	11/−	5/*C. parvum*
4/4/00	Brook JF		ND	+	QNS[f]	QNS[f]
10/23/00	Stillwater River		+	ND		
11/7/00	Quinapoxet River	QR1.5, QR2	−	+	6/−	2/*C. parvum*
12/5/00	Stillwater River	SR1.5, SR2	−	+	10/−	6/*C. baileyi*
12/5/00	Quinapoxet River		+	−		

[a] That is, month/day/year.
[b] Results of MDC samples processed by IFA: +, presumptive positive for *C. parvum*; −, not found.
[c] 1/+, One nested PCR clone was cut with *Nde*I; 11/−, eleven nested PCR clones were not cut with *Nde*I. For samples 3/1/99 and 7/12/99, the complete nested-PCR products were not cut with *Nde*I (the nested-PCR clones were not digested individually).
[d] 3/*C. muris*, the nucleotide sequences of three nested-PCR clones were most closely related to those of *C. muris*.
[e] ND, not done.
[f] QNS, quantity not sufficient.

TABLE 2. Results of fecal sampling

Sample (date)[a]	Location	Sample identification	Source	Nested PCR	*Nde*I digest[b]	Sequence results[c]
6/26/00	Farm SF		Adult cattle	−		
6/26/00	Farm JF	Cow	Adult cattle	+	5/−	2/*C. baileyi*
			Calves	−		
		Manure	Manure pit	+	11/−	3/*C. muris*
8/21/00	Wachusett Reservoir		Geese	−		
			Deer (old)[d]	−		
		Deer	Deer (fresh)	+	3/−	3/*C. parvum*
			Geese and cormorant[e]	−		
		Cormorant	Cormorant	+	9/−	3/*C. baileyi*

[a] See Table 1, footnote *a*.
[b] 5/−, five nested PCR clones did not digest with *Nde*I.
[c] 2/*C. baileyi*, the nucleotide sequences of two nested-PCR clones were most closely related to those of *C. baileyi*.
[d] Dessicated deer feces.
[e] That is, a mixture of geese and cormorant feces.

ridium species. Thus, oocysts identified by IFA must be assumed to be infectious in order to protect public health. By our molecular method, we were able to identify *C. muris* in a sample presumed to be positive for *C. parvum* by IFA (sample 7/12/99), illustrating the importance of species-level oocyst detection. A second limitation of IFA is the possibility that sample debris cross-reacting with the fluorescent antibodies may lead to false-positive reports. We believe this is the most likely explanation for samples that were determined to be positive for *Cryptosporidium* by IFA (samples 2/22/00 and 12/5/00) but negative by our molecular method. We believe our results for these samples are true negatives because we have shown that a single oocyst can be detected under ideal circumstances (Fig. 3) and have run controls that discount the likelihood of PCR inhibitors (Fig. 4). Although we do not routinely run controls for PCR inhibitors, they should be sufficiently removed during filtration and IMS (13, 16, 30). Third, low numbers of oocysts in the environment may go undetected by IFA due to sample dilution and competition of sample debris with fluorescent antibodies. We also identified *Cryptosporidium* oocysts (*C. parvum* and *C. baileyi* [samples 11/7/00 and 12/5/00, respectively]) in water samples that were negative by IFA.

Although some of the differences between IFA and our molecular method may be explained by the random distribution of oocysts in the water (i.e., if the concentration of oocysts in surface water is low, one filter may trap an oocyst while another filter running simultaneously does not), our data suggest that it is possible to incorrectly estimate the public health threat for cryptosporidiosis with conventional IFA analyses. Not all *Cryptosporidium* species in the environment are *C. parvum*. In fact, *C. baileyi* and *C. muris* were identified more often than *C. parvum* in the water samples analyzed in the present study (Table 1). Of the wildlife fecal samples analyzed (Table 2), *C. parvum* oocysts were found in fresh deer stool only. In contrast, *C. baileyi* was found in fecal samples from cormorants and adult dairy cattle, and *C. muris* was identified in a dairy farm manure pit. To our knowledge, infection by *C. baileyi* in cattle has never been described. We speculate that the feed may have been contaminated with *C. baileyi* by birds on the farm and that the oocysts passed transiently through the cattle (the cattle were passing normal feces). The fact that no *C. parvum* oocysts were isolated from the dairy farm cattle or the manure pit is especially pertinent since dairy cattle are considered a major source of infectious oocysts. Also relevant is the fact that *C. muris* (and not *C. parvum*) was identified in the manure pit on farm JF and in Brook SF (where the suspected source of oocysts is agricultural runoff) in sample 3/1/99. A recent study (21) proposed that the large form of *Cryptosporidium* (previously thought to be *C. muris*) infecting the abomasum of cattle is a new species, *C. andersoni*; however, the lack of 18S rRNA sequence data in GenBank precludes the identification of *Cryptosporidium* oocysts in our samples as *C. andersoni* instead of *C. muris*.

Phylogenetic analysis of the sequence data derived from our water and fecal samples indicate that the oocysts isolated from both wildlife and dairy farm fecal samples are closely related to the oocysts found in surface waters in the Wachusett Reservoir watershed (Fig. 5). The fact that we found a mixed population of oocysts in sample 2/1/00 at Stillwater River (*C. parvum* and *C. muris*) suggests that either one source may harbor multiple oocyst species or that multiple sources exist for this site. Because wildlife are abundant in the area, the existence of multiple sources is plausible. *C. muris* appeared to be more abundant than *C. parvum* at this site (as indicated by the fact that only 1 of the 12 nested-PCR clones had the *C. parvum*-like *Nde*I restriction pattern). Additional studies to determine whether wildlife are a significant source of oocysts pathogenic for people are therefore needed.

Our data also indicate a seasonal pattern in oocyst contamination of surface waters. Water samples positive for oocysts were limited to late fall, winter, and early spring (Table 1). No oocysts were found in water samples between mid-April and mid-October with one exception (sample 7/12/99). High-risk periods for oocyst contamination are often thought to be linked to calving season in late winter and early spring, but the detection of oocysts in late fall and early winter suggests that additional factors are operating. The observed seasonal pattern correlates well with temperature; the maximum water temperature at which positive samples were found during 2000 was 9°C. Given that wildlife and dairy farm fecal samples collected in the summer (when water temperatures were >9°C) were positive for *Cryptosporidium* oocysts, it appears

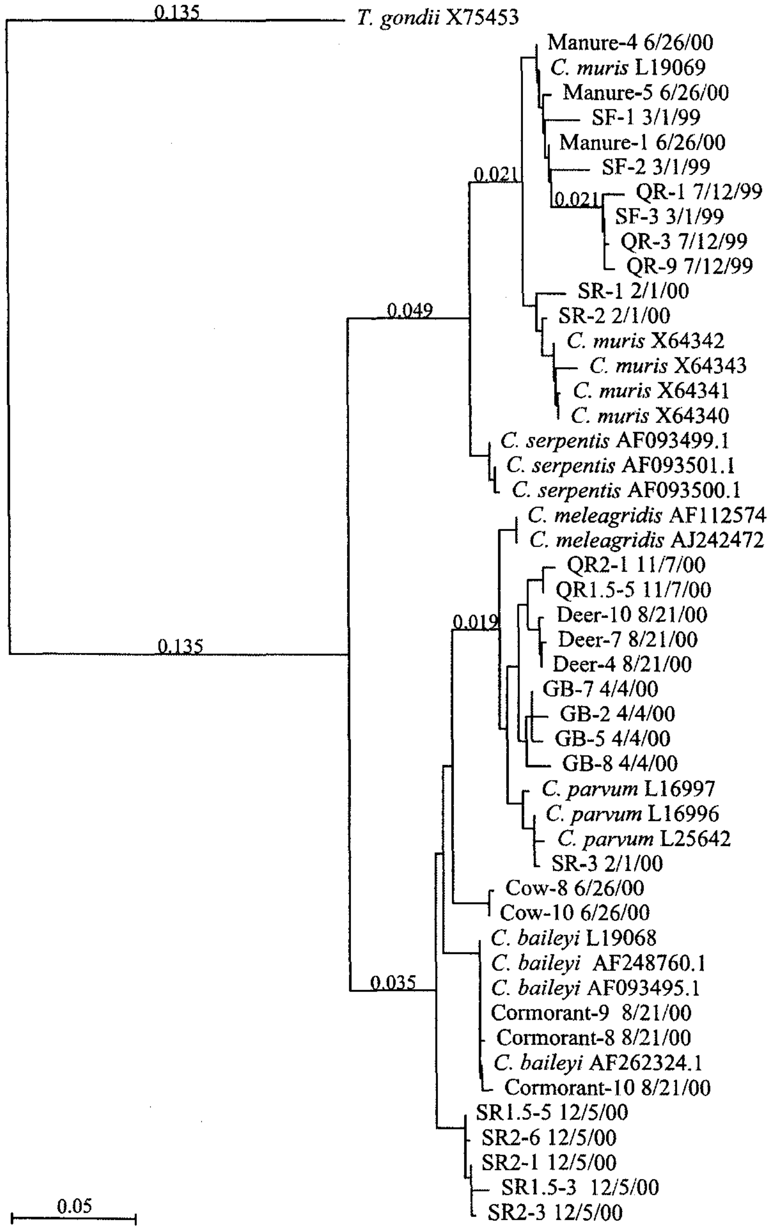

FIG. 5. Phylogenetic relationships among field samples and GenBank *Cryptosporidium* sequences (2, 5, 11, 15, 18, 31–33, 35–37). Phylogeny based upon multiple sequence alignments performed with MacVector 7.0 by using the Tamura-Nei algorithm. A distance of 0.10 indicates a 10% difference between sequences. Field samples are labeled as follows: source-clone no. date sampled (e.g., "Manure-4 6/26/00" denotes clone 4 of manure sampled on 26 June 2000).

that oocysts are present in the watershed year round. Although hydrologic factors are often and probably correctly thought to influence oocyst transport to streams, it is also possible that grazers or predators may limit surface water populations of *Cryptosporidium* in the summer. Possibly other chemical or biotic factors limit oocyst survival in surface waters in warmer temperatures.

The nested-PCR protocol described here can be helpful in the identification of sources and species of oocysts in watersheds, as well as the times of year when surface waters are most susceptible to oocyst contamination. Such information will aid in the development and implementation of the most appropriate watershed management policies and water treatment technologies to protect the public from exposure to *C. parvum*.

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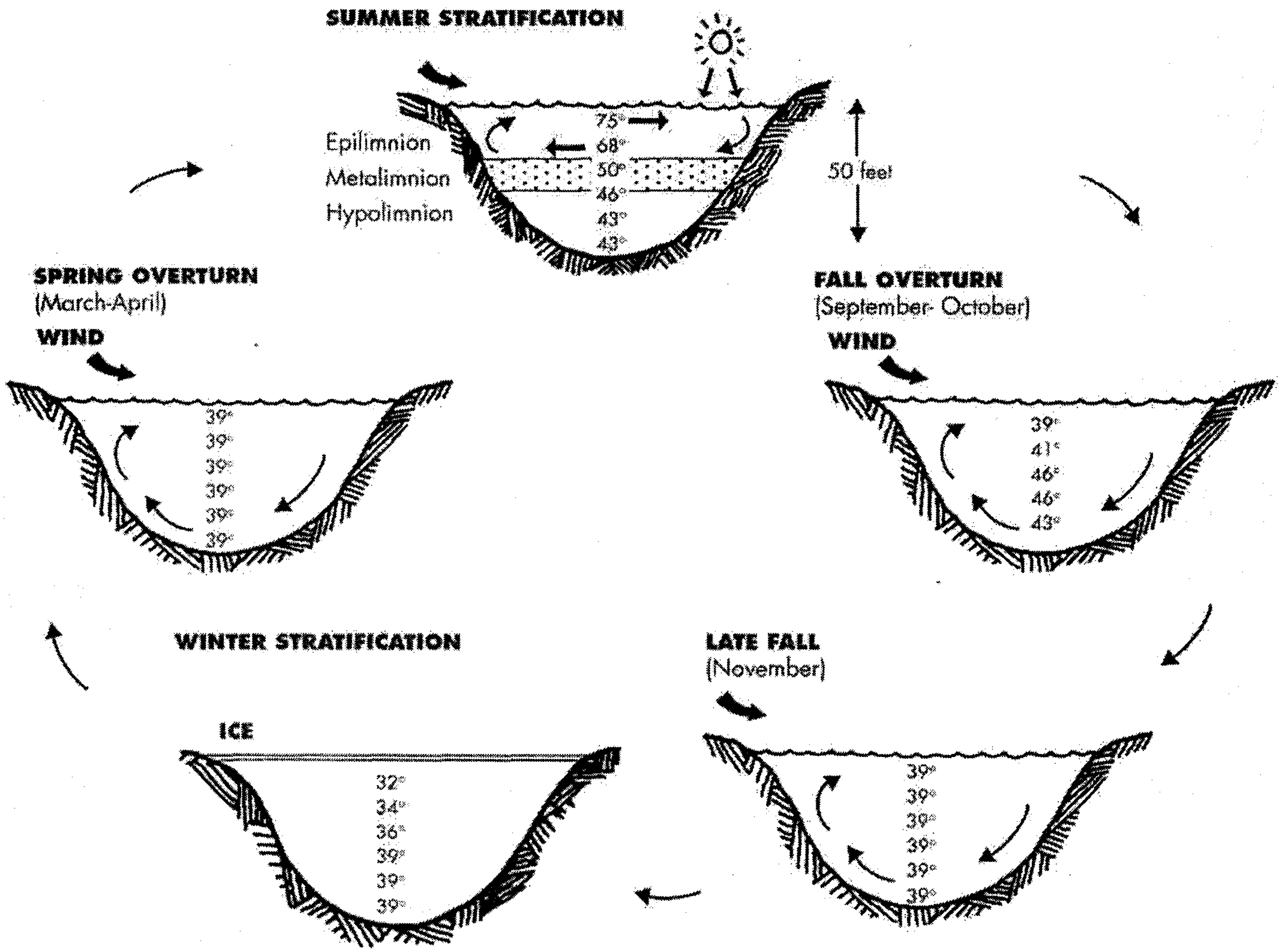
Exhibit 14

FIGURE 2. Annual temperature cycles in stratifited lakes



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Produced by: Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat Protection
More information on this topic: James Vennie Lake Data Manager, Fisheries Management and Habitat Protection Bureau 608-266-2212

Mixing and stratification - Understanding Lake Data

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- **PHYSICAL CHARACTERISTICS - Page 4**
  - ### Mixing and stratification

A lake's water quality and ability to support fish are affected by the extent to which the water mixes. The depth, size and shape of a lake are the most important factors influencing mixing, though climate, lakeshore topography, inflow from streams, and vegetation also plays a role.

Water density peaks at 39 Deg. F. It is lighter at both warmer and colder temperatures. Variations in density caused by different temperatures can prevent warm and cold water from mixing.

When lake ice melts in early spring, the temperature and density of lake water will be similar from top to bottom. The uniform water density allows the lake to mix completely, recharging the bottom water with oxygen and bringing nutrients up to the surface.

This is called **spring overturn**. As surface water warms in the spring, it loses density. Wind and waves can circulate the warmed water only 20 to 30 feet deep, so deeper areas are not mixed. If the lake is shallow (less than 20 feet), however, the water may stay completely mixed all summer.

During the summer, lakes more than 20 feet deep usually experience a layering called **stratification**. Depending on their shape, small lakes can stratify even if they are less than 20 feet deep. In larger lakes, the wind may continuously mix the water to a depth of 30 feet or more. Lake shallows do not form layers, though deeper areas may stratify.

Summer stratification, as shown in Figure 2, divides a lake into three zones: **epilimnion** (warm surface layer), **thermocline** or **metalimnion** (transition zone between warm and cold water), and **hypolimnion** (cold bottom water). Stratification traps nutrients released from bottom sediments in the hypolimnion. In the fall, the surface cools until the water temperature evens out from top to bottom, which again allows mixing **(fall overturn)**. A fall algae bloom often appears when nutrients mix and rise to the surface.

Winter stratification, with a temperature difference of only 7 Deg. F (39 degrees on the lake bottom versus 32 degrees right below the ice), remains stable because the ice cover prevents wind from mixing the water.

The lake's orientation to prevailing winds can affect the amount of mixing that occurs. Some small, deep lakes may not undergo complete mixing in the spring or fall if there is not enough wind action. The mixing that takes place in the bays of a large lake will more closely resemble that of a small lake because the irregular shoreline blocks the wind.

Because mixing distributes oxygen throughout a lake, lakes that don't mix may have low oxygen levels in the hypolimnion, which can harm fish. Some fish species require lake stratification. The cold water in the hypolimnion (bottom) can hold more oxygen than warmer water in the epilimnion (top) and thus provide a summer refuge for cold water fish such as trout. But if the lake produces too much algae, which fall into the hypolimnion to decay, oxygen becomes depleted. The steep temperature gradient of the metalimnion prevents any surface water with dissolved atmospheric oxygen from reaching the bottom waters.

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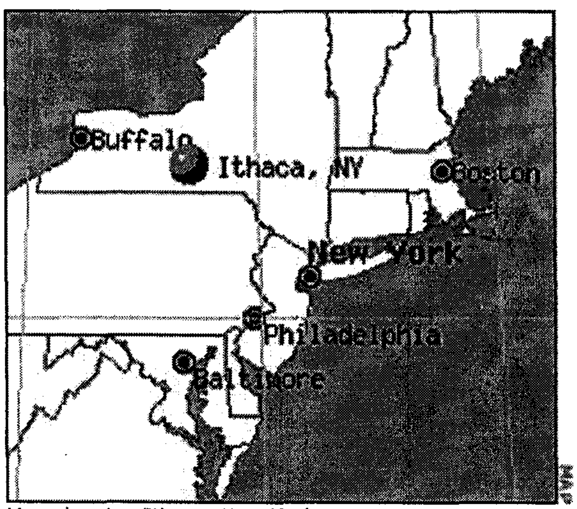
Exhibit 15

Typhoid

In the beginning of the 20th century, the threat of a national epidemic was very real. Though great strides were made during the previous fifty years in the field of epidemiology, people still lived in fear of contagious diseases. That fear was well-justified. During the Civil War period, more deaths were caused by disease than battle wounds. Typhoid and dysentery together claimed over 280,000 lives during that conflict. It was also believed that over 35,000 deaths were attributed nationwide to typhoid in 1900 alone. Many diseases spread rapidly due to sub-standard sanitary conditions and a lack of understanding as to how they were transmitted. Typhoid was especially feared because it seemed to be everywhere and outbreaks of the sickness seemed common.



Map showing Ithaca, New York

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CHAPTERS

In 1903, an epidemic of typhoid struck the city of Ithaca, New York. In its initial stages, the sickness was misdiagnosed as a type of flu. Within a few weeks, hundreds were infected. Only then was the correct diagnosis made. Within four months, the Health Department counted 1,350 of the city's 13,000 residents sick with typhoid, and 85 eventually died. To place these numbers in perspective, if a similar outbreak occurred in New York City today, over 800,000 people would be afflicted. "To date 19 Cornell students have died from typhoid," reported the New York Times, "of whom 18 were male students. This makes almost 1 per cent of the male students of Cornell who have died of the fever within three weeks" (March 3, 1903). In a state of panic and unable to understand how the epidemic progressed, the City Council of Ithaca hired Dr. George A. Soper, a sanitary expert, who had studied typhoid and how it was transmitted in humans.

Soper immediately tested the city's water supply and discovered a large portion of the system was infected with typhoid bacillus. Further investigation revealed that an antiquated sewage system allowed cesspools to drain directly into clean creeks and streams. In other words, human waste was leaking into the water supply. Soper took steps to correct the problem by upgrading the sewage system and sealing up the infected areas. These measures stopped the disease in its tracks, and undoubtedly many deaths were averted. But it was still not clear how the epidemic got started in the first place.

Did it just naturally develop in the

contaminated wells? Did someone intentionally bring the typhoid germ to Ithaca? Even Soper himself could not answer those questions.